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AMPLITUDE PATTERN EFFECTS ON NORSAR P-WAVE DETECTABILITY

K. A. Berteussen, et al

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A detailed mapping of NORSAR P-wave amplitude anomalies as a function of the array's beam locations has been performed. For several regions there is as much as 20 dB amplitude variations across the array. There is, however, usually less than 0.3 dB to gain in signal-to-noise ratio by excluding one or more of the NORSAR subarrays. Moreover, one will have to use very small regions, i.e., one set of weights for each of the Detection Processor beams. This because the amplitude pattern, although stable for events coming in on the same beam, may change very drastically from one beam location to

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the nearest one. Although some of the subarrays have small amplitudes for most of the seismic regions covered by NORSAR, they all have regions where they have the largest amplitude. Therefore, in average there will always be some loss by excluding any of the subarrays consistently.

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SUMMARY

A detailed mapping of NORSAR P-wave amplitude anomalies as a function of the array's beam locations has been performed. For several regions there is as much as 20 dB amplitude variations across the array. There is, however, usually less than 0.3 dB to gain in signal-to-noise ratio by excluding one or more of the NORSAR subarrays. Moreover, one will have to use very small regions, i.e., one set of weights for each of the Detection Processor beams. This because the amplitude pattern, although stable for events coming in on the same beam, may change very drastically from one beam location to the nearest one. Although some of the subarrays have small amplitudes for most of the seismic regions covered by NORSAR, they all have regions where they have the largest amplitude. Therefore, in average there will always be some loss by excluding any of the subarrays consistently.

INTRODUCTION

The large scatter in short period P-wave amplitude observations has puzzled seismologists for a long time, as this phenomenon is not satisfactorily explained in terms of ray theory and homogeneous spherically layered earth models. A viable alternative here is to use the Chernov (1960) theory for acoustical wave propagation in random media as shown by Aki (1973) and Capon (1974). A demonstration of the usefulness of the Chernov theory has been given by Berteussen et al (1974) who in this way was able to explain around 60% of the variance in P time and amplitude anomalies observed across the NORSAR array.

A proper understanding of the physical mechanism underlying the observed P wave amplitude variations is a prerequisite for taking advantage of this kind of information in seismological data analysis. For example,

according to random medium theory, the amplitudes are expected to have a lognormal distribution. This is in fact observed across NORSAR (Ringdal et al, 1972). The statistical amplitude model has been used by Husebye et al (1974) in an investigation of possible bias effects in NORSAR-reported m_b magnitudes. Christoffersson and Husebye (1974) have demonstrated that improved beamforming gain in SNR is possible using a least squares amplitude weighting scheme while Fyen et al (1974) have found that the most decisive piece of information for statistical signal-noise classification is the skewness in the amplitude distribution.

The above studies show that not only the background noise is important for the design of data processing algorithms, but also the amplitude pattern across the array. Although the P-wave amplitudes across NORSAR could be approximated by a lognormal distribution, a distinct, stationary pattern exists for each seismic region. The purpose of this report is a detailed mapping of NORSAR P wave amplitude anomalies as a function of array beam locations. The impact of this information on the array's event detectability will also be discussed in detail.

ARRAY BEAMFORMING THEORY

The operational principles of seismic arrays are based on the assumption that the P signals are identical across the array while the noise is Gaussian and approximately uncorrelated from one sensor to another. For a signal model of the above kind, the optimum estimate of an incoming signal, as sampled by the sensors in the array, is simple delay-and-sum processing or beamforming. The expected gain in SNR is proportional to $\sqrt{N}$ where N

is number of sensors in the array. In practice, the above, rigid assumptions on noise and signal properties are only approximately valid resulting in an SNR beamforming gain a few dB less than that corresponding to $\sqrt{N}$. More sophisticated array data processing schemes may give better results, e.g., a relative SNR improvement of the order of 2-3 dB was obtained both for NORSAR and LASA arrays as demonstrated by Christoffersson and Husebye (1974) using a least squares signal estimation technique. (As a general introduction to the Wiener theory commonly used in multichannel seismic data processing, we refer to Kailath, 1974.)

An important task of the NORSAR array (for description see Bungum et al, 1971, and Bungum and Husebye, 1974) is seismic surveillance, that is, a real-time signal processing system for detection of seismic events. In this respect, the simple beamforming technique is preferred due to its computational simplicity which is a requirement for real-time analysis of array data. Therefore, in this section we will give a brief presentation of the beamforming theory, emphasizing the gain in SNR when the basic assumption of identical signals is not strictly valid.

Let us assume we have N seismic sensors distributed on the earth's surface. The output from these is sampled at certain fixed intervals; the i-th sample from sensor j is denoted a_{ji}. The power of the i-th trace is defined as

$$A_i^2 = \frac{1}{STA} \sum_{j=1}^{STA} a_{ij}^2$$

where STA is number of samples. The power of the sum of the N traces, S_{AB}^2, is then given by

$$S_{AB}^2 = \frac{1}{STA} \sum_{i=1}^{STA} (a_{1i}+a_{2i}+\ldots+a_{Ni})^2 \qquad (1)$$

It is assumed that proper time delays have been introduced so the signals are in phase or correctly lined up. Performing the squaring operation in eq. (1) one gets

$$S^2_{AB} = \frac{1}{STA} \sum_{i=1}^{STA} (a_{1i}{}^2 + a_{1i} \cdot a_{2i} + \ldots + a_{1i} a_{N} i + \quad (2)$$
$$a_{2i} \cdot a_{1i} + a^2_{2i} + \ldots + a_{2i} a_{Ni} +$$
$$\vdots$$
$$a_{Ni} a_{1i} + a_{NI} a_{2i} + \ldots + a^2_{Ni})$$

Performing the summation one gets

$$S^2_{AB} = (A^2_1 + A_1 A_2 \rho_{12} + \ldots + A_1 A_N \rho_{1N} +$$
$$A_2 A_1 \rho_{21} + A^2_2 + \ldots + A_2 A_N \rho_{2N} + \quad (3)$$
$$\vdots$$
$$A_N A_1 \rho_{N1} + A_N A_2 \rho_{N2} + \ldots + A^2_N)$$

where A^2_i denotes the power of trace i, and ρ_{ij} is the normalized correlation coefficient between sensor i and j. Eq. (3) may be written in matrix form

$$S^2_{AB} = \{A_1, A_2, \ldots, A_N\} \begin{Bmatrix} 1, \rho_{12}, \ldots, \rho_{1N} \\ \rho_{21}, 1, \ldots, \rho_{2N} \\ \vdots \\ \rho_{N1}, \rho_{N2}, \ldots 1 \end{Bmatrix} \begin{Bmatrix} A_1 \\ A_2 \\ \vdots \\ A_N \end{Bmatrix} \quad (4)$$

$$= A \; R_S \; A'$$

where A is a row vector consisting of the elements A_i, $i=1,N$ and R_S is the signal correlation matrix. A' is the transpose of A. If noise is present, the same formula still applies. For example, letting B be a row vector consisting of N elements where B_i represents noise power for instrument i, and letting R_N be the noise correlation matrix, we find that the signal-to-noise ratio, SNR, on the summed trace may be calculated from the ratio

$$SNR^2 = \frac{A \cdot R_S \cdot A'}{B \cdot R_N \cdot B'} \tag{5}$$

If all elements in A are equal to $\sqrt{\bar{a}^2}$ and $\rho_{ij} = \bar{\rho}_s$ for $i \neq j$ in the matrix R_S, eq. (3) gives

$$S^2_{AB} = \bar{a}^2 (N + (N-1) \cdot N \cdot \bar{\rho}_s) = \bar{a}^2 \cdot N (1 + (N-1) \bar{\rho}_s) \tag{6}$$

If the same assumptions are valid also for noise we get the familiar expression

$$SNR^2_{AB} = \frac{\bar{a}^2 \cdot N \cdot (1 + (N-1) \rho_s)}{\bar{n}^2 \cdot N \cdot (1 + (N-1) \rho_N)} \tag{7}$$

For $\rho_s = 1$ and $\rho_N = 0$ this again reduces to $SNR^2_{AB} = \frac{\bar{a}^2}{\bar{n}^2} \cdot N$; that is, the gain in SNR increases with $\sqrt{N}$.

<u>Example 1</u>: Let us assume we are summing two traces whose signal power is given by A_1 and A_2 respectively. ρ_{12} is assumed equal to 1 for the signals and 0 for the noise, and the noise level is supposed equal to $\bar{n}^2$ on both traces. The signal-to-noise ratio of the summed trace is then found from

$$SNR^2_{AB} = \frac{(A_1 + A_2)^2}{2\bar{n}^2}$$

while the corresponding value for trace 1 is $A_1^2/\bar{n}^2$. In order to have a gain in SNR by summing the two traces, one must have

$$\frac{(A_1+A_2)^2}{2\bar{n}^2} > \frac{A_1^{\,2}}{\bar{n}^2}$$

i.e., $A_2 > (\sqrt{2}-1) \cdot A_1 \approx 0.41 \cdot A_1$. That is, if the amplitude of the second trace is less than 0.41 (7.7 dB) times the amplitude of trace one, adding the two traces does not give a gain in signal-to-noise ratio, even though they have exactly the same signal shape. If $\rho_{12}=0.7$, which is a reasonable value for P-signals recorded at NORSAR, the criterion is $A_2>0.52 \cdot A_1$ in order to have a gain in signal-to noise ratio by summing the two traces.

Example 2: Let us assume we have already summed 21 traces, all with the same amplitude, $\bar{A}$, and shape. The noise level is as before assumed equal on all traces and completely uncorrelated from one trace to another. The signal-to-noise ratio would then be $SNR_{21}^2 = \dfrac{A^2 \cdot 21 \cdot 21}{n^2 \cdot 21}$.

Adding to this a trace no. 22 of the same shape but with amplitude A_{22} gives:

$$SNR_{22}^2 = \frac{(\bar{A} \cdot 21 + \bar{A}_{22})^2}{n^2 \cdot 22}$$

Requiring SNR_{22} greater than SNR_{21} gives:

$$A_{22} > (\sqrt{22 \cdot 21} - 21) \cdot \bar{A} \approx 0.49 \cdot \bar{A}$$

That is, in order to have a gain in signal-to-noise ratio, A_{22} must have an amplitude which is not less than 0.49 (6.12 dB) times the amplitude of the other traces.

Example 3: Let us assume that in the above case A_{22} is equal to zero. This gives $SNR_{22} = SNR_{21}\sqrt{\frac{21}{22}}$, that is, the result would be a loss of 0.2 dB in signal-to-noise ratio.

Example 4: Let A_{22} in ex. 2 be equal to $\bar{A}$, but exactly 180° out of phase; this gives $SNR_{22}^2 = \frac{(\bar{A}\cdot 21-\bar{A})^2}{n^2\cdot 22}$. That is, the result would be a loss of 0.6 dB in signal-to-noise ratio.

DATA ANALYSIS

The data used have been established by measuring subarray and array beam amplitudes on P-waves recorded at NORSAR during 1972 and 1973. All events which were not clipped and had a signal-to-noise ratio (SNR) above 6.5 have been used. Before calculating the amplitudes the traces were filtered with a 1.2-3.2 Hz bandpass (3rd order Butterworth) filter. Totally this gave 964 events. The computerized method of calculating amplitudes is described in Husebye et al (1974). The data have been grouped according to which of the NORSAR Detection Processor (DP) beam locations (Appendix 1) the events were closest to. As was observed by Husebye et al (1974) the amplitude pattern is approximately stationary from one event to the other as long as the events are close enough in slowness and azimuth. This is demonstrated in Table 1, which lists the amplitude loss in dB relative to the best subarray for a set of events detected on DP beam location 188.

EVENT I.D.	SUBARRAY NUMBER																					
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	AB
40800	18	6	8	-	16	16	18	11	5	4	0	10	7	18	9	19	21	16	12	5	10	15	11.2
41530	15	5	8	9	14	14	-	12	4	4	0	10	9	18	9	14	18	16	12	4	10	14	10.4
78890	16	6	8	10	13	12	22	14	5	1	0	11	7	16	10	15	19	17	12	8	9	13	11.3
17310	14	6	8	6	12	19	18	11	7	6	0	14	6	17	11	13	14	16	-	6	13	11	11.2
65000	14	7	7	10	15	14	14	10	4	7	0	14	9	14	9	15	15	13	11	5	11	-	11.8
74660	13	8	7	4	12	11	18	13	4	5	0	13	7	16	11	9	12	14	13	9	7	15	13.6
49570	17	6	8	8	16	15	17	11	5	3	0	10	7	16	9	20	18	-	12	4	12	18	10.8
53910	14	5	8	7	16	18	15	10	4	8	0	8	6	14	9	15	21	15	9	4	7	-	10.0
79370	14	6	5	9	13	14	13	11	5	7	0	11	9	15	6	13	15	18	12	6	11	13	11.8
2180	12	6	7	8	13	14	14	10	5	6	0	14	8	18	8	-	18	18	11	6	12	14	12.0
32550	15	5	6	5	14	11	13	8	2	5	0	11	7	16	2	15	14	15	7	1	12	18	9.3
38270	18	6	8	9	15	14	17	11	4	5	0	12	7	17	9	17	19	17	13	6	11	16	11.7
79230	12	6	9	8	-	14	17	10	3	5	0	10	6	13	10	14	17	14	12	8	9	9	11.2
85910	15	5	7	8	18	14	17	9	4	5	0	11	7	18	7	15	15	15	12	5	11	15	10.7
52240	11	7	7	7	16	15	17	10	8	8	0	7	7	17	11	13	-	13	9	6	12	11	11.1
17630	14	9	9	9	18	16	15	12	5	6	0	6	-	17	12	12	18	15	13	5	12	12	12.4
69380	13	-	9	10	16	15	12	14	6	5	0	9	7	14	11	13	13	17	13	4	12	12	12.7
53970	14	7	9	10	16	13	15	11	6	3	0	8	6	14	11	13	14	16	11	5	9	-	11.1
58810	12	4	7	8	16	12	17	11	7	1	0	10	6	14	10	14	20	15	12	5	10	-	11.7

TABLE 1

Subarray and Array Beam (AB) amplitude losses in dB for events detected on NORSAR Detection Processor (DP) beam no. 188. This beam is pointed towards 37N, 71E (Afghanistan-USSR Border). As seen from the table subarray 11 is best for all events analyzed. The loss values are relative to the best subarray.

The Kendal coefficient of concordance (Siegel, 1956) has been computed for this data set. Subarray 22 was excluded from analysis, and also those events where any of the other subarrays were out of operation. This coefficient is equal to 1.0 if the amplitude ranking pattern is reproduced from one event to another, but would be zero if the pattern is completely random. The value obtained was 0.83. The chance of randomly getting such a large value is less than 0.001. This coefficient has also been calculated for the 5 beams where most data is available (Beam nos. 36, 63, 115, 288 and 289). The average value is 0.8 ± 0.1, and for any of the 5 beams the chance of randomly getting a value as extreme as that obtained is less than 0.001.

In Table 2 are listed the average of observed amplitude values, measured in dB down from the best subarray's value, for the different subarrays for selected DP beams. (The whole table is listed in Appendix 2.) The last column in Appendix 2 gives the amplitude values of the full array beam relative to the best subarray. In Table 3 the data have been averaged over larger regions, which are defined in Table 4 and depicted in Fig. 1. These correspond closely to those used by Bungum and Husebye, 1974.

Beam No.	SUBARRAY NUMBER																						Array Beam
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	
6	3	9	5	10	13	10	3	4	5	12	9	2	0	9	5	8	8	10	8	8	8		8
9	2	6	3	9	11	8	1	5	4	8	6	3	1	12	5	6	7	10	12	5	5	4	7
11	1	7	5	9	6	9	7	5	5	5	4	5	4	12	10	4	7	8	7	5	9	0	8
12	0	5	6	12	10	6	2	6	8	7	8	4	0	12	8	5	6	12	11	4	8	1	7
15	1	7	6	11	11	7	3	3	8	6	7	4	2	9	2	3	7	10	10	6	7	4	7
16	3	10	8	11	11	11	0	6	3	4	5	5	4	7	6	3	4	7	5	10	7	6	8
17	0	8	8	17	10	7	6	8	8	6	7	4	2	9	3	2	8	8	12	8		6	8
20	6	6	7	9	6	11	1	4	4	5	2	5	4	8	8	5	6	8	3	6	4	4	9
21	13	14	6	9	10	14	5	9	6	6	0	2	0	8	8	4	7	6	3	3	6	6	7
23	14	13	7	13	13	15	4	9	7	8	0	3	0	10	8	5	7	8	3	5	9	5	8
24	14	14	5	12	12	13	5	9	8	7	0	2	1	11	8	5	6	6	2	4	8	7	8
25	8	15	2	11	9	12	11	13	2	2	1	3	3	10	9	4	11	8	6	1	4	5	9
26	11	15	2	14	6	13	14	15	5	5	5	5	1	11	9	10	11	12	15	2	6	6	9
27	9	11	3	8	7	8	12	13	1	2	3	4	1	10	11	11	11	14	12	3	3	6	8
29	5	8	0	2	10	10	9	15	5	7	3	8	6	11	14	11	3	13	15	11	5	9	9
31	13	15	4	10	6	13	14	15	3	5	6	6	1	11	9	8	10	13	13	3	6	7	10
32	9	13	4	10	5	10	12	16	3	8	3	4	0	8	7	6	8	13	11	4	5		8
33	8	10	3	6	4	8	14	14	3	3	4	2	1	10	8	8	6	13	13	4	4	15	9
34	6	11	0	2	9	9	13	19	3	0	3	5	4	10	14	9	8	14	17	9	6	9	9
35	8	13	1	4	4	5	10	15	3	1	2	1	1	9	11	8	9	14	14	6	3	7	7
36	5	9	0	3	12	12	8	14	3	6	4	8	9	13	14	13	2	10	16	13	7	11	9
37	5	9	0	1	10	10	8	18	4	5	4	9	7	14	16	12	0	9	16	13	6	11	8
42	7	7	1	5	11	11	6	10	3	5	2	5	6	11	9	10	2	9	13	12	8	11	9
43	7	7	1	6	10	12	4	10	2	4	4	5	5	11	9	10	1	6	12	10	7	9	8
48	3	4	8	4	9	6	7	3	4	6	2	11	10	6	8	9	8	0	9	6	10	8	8
50	8	11	0	3	9	12	5	11	3	6	5	6	2	11	9	10	5	7	11	12	12	12	8
52	10	13	1	6	9	14	9	13	8	9	5	5	0	10	11	11	11	9	14	15	16	17	11
53	8	8	0	8	11	13	6	12	7	10	7	5	2	12	15	14	12	6	13	13	15	17	11
55	14	10	9	0	11	18	16	10		15	6	16	16	8	10	11	15	10	13	15	14	18	12
56	9	7	8	1	6	7	11	7	8	9	1	13	6	0	5	7	5	3	12	8	8		9
58	9	10	0	8	10	14	8	14	9	10	8	4	2	13	16	14	13	7	14	14	17	18	11
60	8	6	9	0	15	5	12	2	4	10	2	6	2	1	3	8	6	11	14	8	10	11	9
62	8	7	8	0	12	16	12	12	9		5	18	15	10	8	7	11	8	9	15	15	17	10
63	8	4	0	7	12	15	7	12	7	8	7	6	4	13	17	14	14	5	13	12	16	15	11
64	7	4	0	8	12	15	6	8	3	6	3	5	3	14	16	14	11	3	12	9	16	11	9
65	8	1	2	10	9	14	8	3	0	2	1	7	2	13	12	14	9	2	8	2	8	4	8
70	8	4	2	9	10	13	7	4	1	1	4	4	3	12	12	9	9	5	9	7	14	12	8
71	8	4	3	10	11	14	8	5	0	4	4	5	3	12	12	12	10	5	10	6	13	11	9
73	6	6	6	0	8	9	7	4	6	10	7	12		6	6	3	1	2	8	8	6	8	8
74	8	8	7	0	10	8	7	8	8	8	6	8	9	8	10	7	6	4	7	8	6		10
75	9	6	6	11	11	14	8	7	0	4	9	6	2	14	12	12	9	7	10	7	15	12	9
76	9	6	7	11	11	15	8	6	1	5	9	6	1	15	12	13	10	9	10	8	16	14	9
77	16	9	2	3	7	12	15	9	5	11	7	7	0	12	5	15	9	12	14	9		14	12
78	9	7	7	12	10	13	9	6	0	3	9	5	3	14	12	12	10	12	11	10	13	14	10
79	16	12	10	15	16	16	12	9	0	5	14	6	2	18	15	17	13	14	12	9	15	18	12
80	12	8	9	13	10	15	10	7	0	4	10	7	3	15	13	13	12	13	12	11	13	15	11

TABLE 2

Average subarray and array beam (AB) amplitudes (in dB down) relative to the best subarray for selected NORSAR Detection Processor (DP) beams. The different beam locations are listed in Appendix 1. The data presented is taken from Appendix 2.

REGION No.	SUBARRAY NUMBER																						
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	AB
1	7	11	5	10	8	10	7	10	5	5	4	3	2	9	8	6	8	10	9	5	6	6	8
2	6	7	7	3	9	10	9	6	7	9	5	11	9	8	8	7	7	5	8	9	9	8	9
3	5	4	3	3	3	5	3	8	10	10	7	6	4	5	10	6	5	6	6	5	6	5	7
4	10	7	8	7	8	11	6	6	8	4	8	10	10	9	8	7	9	5	5	7	8	8	9
5	5	6	3	7	3	4	5	6	5	7	8	4	7	6	3	1	6	8	9	5	6	4	12
6	6	6	7	4	6	8	6	11	11	10	8	3	4	8	8	7	5	5	7	7	7	9	9
7	11	5	6	6	8	10	13	9	6	6	2	6	4	8	8	10	12	10	9	7	8	12	10
8	7	10	5	6	7	10	10	8	3	4	4	4	2	5	5	8	8	6	9	8	7	10	8
9	8	10	7	10	9	12	10	6	4	6	4	2	3	10	8	9	11	11	5	11	4	11	10
10	8	8	3	8	11	13	8	10	4	6	6	6	4	13	13	12	8	8	12	10	12	13	9
11	8	6	7	7	11	4	8	6	11	10	3	13	12	5	8	6	6	7	7	9	3	10	9
12	8	10	6	6	10	3	10	6	13	12	1	10	13	5	11	4	7	7	6	9	4	9	9
13	7	9	10	8	7	4	3	5	9	9	11	10	7	7	11	4	6	5	7	5	8	11	8
14	7	8	6	7	8	9	8	8	6	7	6	6	5	8	8	7	8	8	8	8	7	9	9

TABLE 3

Average subarray and array beam (AB) amplitude values (in dB down) relative to the best subarray, for regions 1 to 14 as defined in Table 4 and also depicted in Fig. 1.

Region	Area of Coverage	Gutenberg & Richter	Flinn & Engdahl
1	Aleutians-Alaska	1	1-17
2	Western North America	2-4	18-52
3	Central America	5-7	53-71
4	Mid-Atlantic Ridge	32	403-414
5	Mediterranean-Middle East	30-31	357-401
6	Iran-Western Russia	29	335-356
7	Central Asia	28	326-334
		47-48	709-720
8	Southern-Eastern Asia	26-27	302-325
9	Ryukuo-Philippines	20-22	231-260
10	Japan-Kamchatka	19	217-230
11	New Guinea-Hebrides	14-16	183-189
12	Fiji-Kermadec	12-13	169-182
13	South America	8	102-142
14	Distance range 30°-180°		

TABLE 4

Regionalization used in this study.

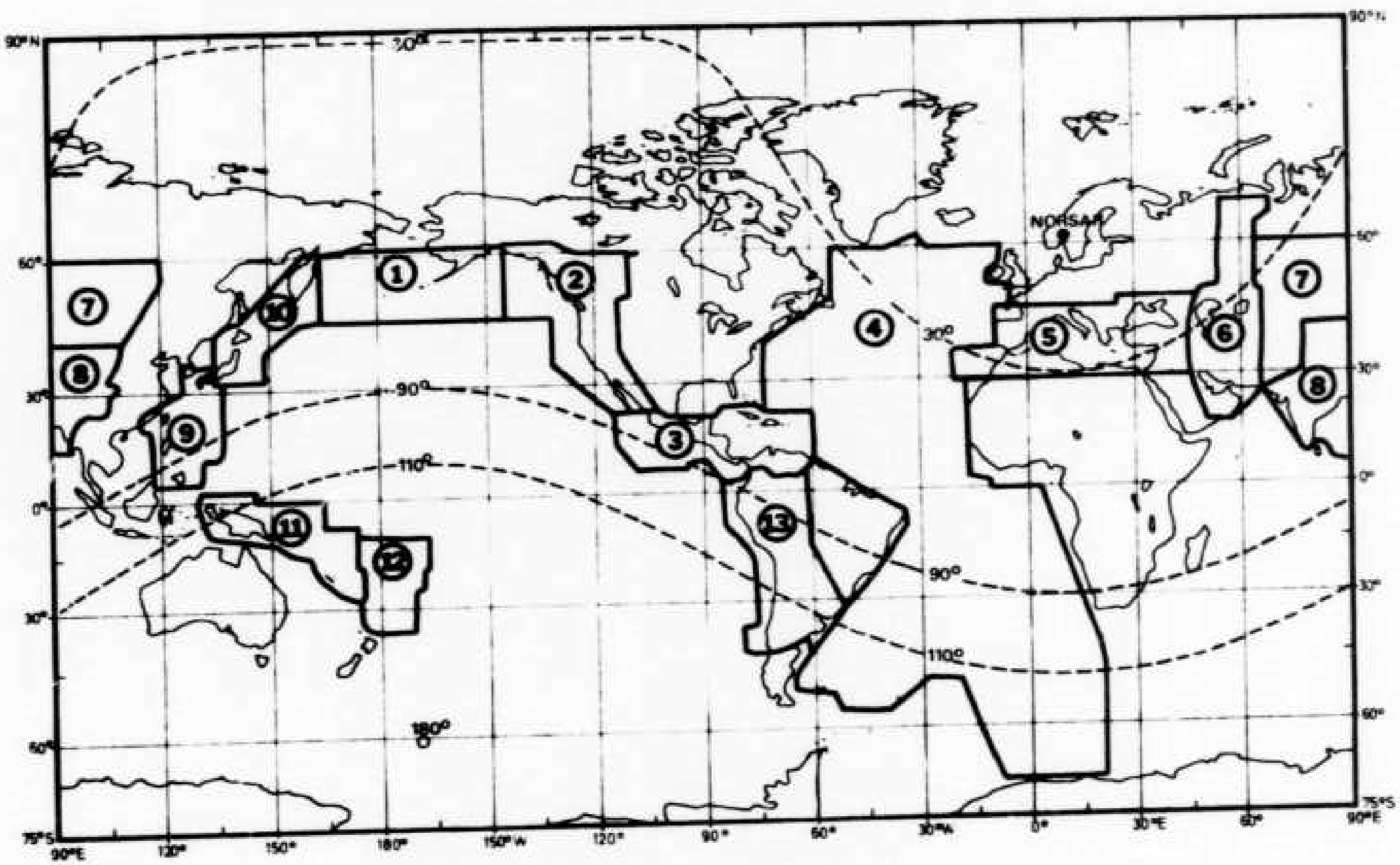

Fig. 1 Map illustrating regionalization used in this study (from Bungum & Husebye, 1974).

RESULTS

As shown in the previous section, also the array beam amplitude has been calculated and compared with the best subarray. Using eq. (4) it is possible to calculate the average signal correlation ($\bar{\rho}_s$) between the different subarrays, when one assumes that the array beam loss is caused solely by lack of correlation. With the $\bar{\rho}_s$ value known and with the additional assumptions that the noise is uncorrelated from one subarray to another ($\bar{\rho}_n$=0) and that the noise level is equal on all subarrays, it is possible, by using eq. (5), to calculate expected SNR loss on the array beam for the case that one or more subarrays are excluded from the beamforming. The procedure has been to calculate the expected SNR for each DP beam when only the subarray with the smallest amplitude is excluded, then the second smallest one is excluded, and so on until only the subarray with the highest amplitude is left.

In Fig. 2 the expected performance for beam no. 91 (South of Honshu) is shown as a function of number of subarrays, where the subarrays have been ranked according to their amplitudes. For this beam, using only the best subarray (no. 13), one would have a loss of 4.6 dB relative to the current array beam. Using the 15 best subarrays would give a gain of 0.15 dB. For this beam it is seen from Appendix 2 that the difference in amplitude between the best subarray (no. 13) and the poorest (no. 22) is as much as 18 dB. Another example. for beam 175 the difference in amplitude between the best (no. 1) and the poorest (no. 17) is only 10 dB, Fig. 3 shows that there is no gain by excluding any of the subarrays in this case.

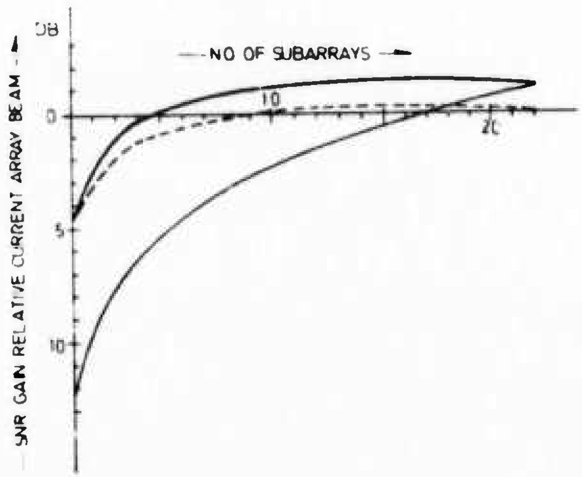

Fig. 2 Expected signal-to-noise ratio as a function of number of subarrays for DP beam 91, pointing towards 29N, 139E (South of Honshu, Japan). The subarrays have been ranked according to their amplitude. The first point on the horizontal axis corresponds to subarray no. 13, which has the highest amplitude in this case. The bottom line shows the theoretical $\sqrt{N}$ performance for the case of identical signals. The relative gain here using all 22 subarrays is 1.2 dB, which implies that the observed array beam signal suffers an average loss of 1.2 dB. The upper line gives the SNR improvement for the case of identical subarray signal shapes, but with the amplitude distribution listed for beam no. 91 in Appendix 2. The figure shows that the subarray no. 13 is in average 4.6 dB below the array beam. A beam based on the 5 best subarrays would have the same SNR as the current array beam. The broken line gives the gain in SNR when the signal correlation is in average 0.75. For this beam the maximum amplitude difference between two subarrays is 18 dB (Appendix 2).

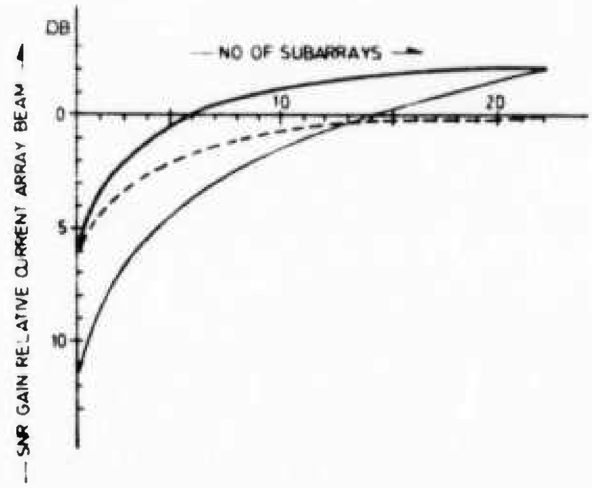

Fig. 3 Same as Fig. 2 for DP beam no. 175 pointing towards 7N, 73 W (Northern Colombia). Subarray no. 1, which is best, is 5.9 dB below the array beam. The maximum difference in amplitude between two subarrays is 10 dB. The broken line shows that nothing would be gained by excluding any of the poorest subarrays. The amplitude loss of the currently used array beam is 2.1 dB.

In Table 5 is listed the number of the very best subarray for some of the DP beams where data was available, and the numbers of those subarrays that should be excluded in order to ensure maximum SNR on this beam. (The entire Table is listed in Appendix 3.) The gain in SNR by excluding these is also listed. For some of the beams (like no. 175) a negative gain value is listed; this means that for these subarrays one would encounter a loss in SNR by excluding any subarrays.

BEAM NO.	BEST SUB.	POOREST SUBARRAYS	GAIN BY EXCLUDING
6	13	5 10	0.20
9	13	19 14 5	0.05
11	22	14	0.02
12	13	4 14 18	0.05
13	22	4	0.01
15	1	5	0.01
16	7	6	-0.01
17	1	4 19	0.11
20	7	6	0.01
21	11	6 2 1	0.14
23	13	6 1 2 4 5	0.20
24	11	1 2 6 4 5	0.19
25	11	2 8 6 4 7 17	0.22
26	13	2 8 19 4 7 6 18 1 14 17	0.31
27	13	18 8 7 19 16 2 15 17	0.10
29	3	8 19 15 18	0.18
31	13	8 2 7 6 18 19 1	0.20
32	13	8 2 18 7	0.10
33	13	22 8 7 18 19	0.26
34	3	8 19 15 18 7 2	0.35
35	13	8 19 18 2 15 7	0.28
36	3	19 8 15 16 20 14 6 5	0.20
37	3	8 19 15 14 20 16	0.31
42	3	19	0.01
43	17	6	0.01
48	18	12	-0.02
50	3	22	0.0
52	13	22 21 20 6 19	0.14
53	3	22 15 21 16 19 6	0.14
55	4	6 22 12	0.06
56	14	12 19 7	0.04
58	3	22 21 15 16 8 19 20 6 17 14	0.23
60	4	5 19 7 22	0.14
62	4	12 22 6 21 20 13	0.24
63	3	15 21 6 22 16 17 19 14 8 20	0.35
64	3	15 21 6 16 14 19 5 17 22	0.38
65	9	16 6 14 15 4	0.26
70	9	21 6 15 22 14	0.07
71	9	6 21 14 15 16	0.04
73	4	12	0.01
74	4	5	0.0
75	9	21 6 14	0.06
76	9	21 14 6 22	0.09
77	13	1 7 16 19 22 18 6 14	0.27
78	9	14	0.0
79	9	22 14 16 5 1 6 4 21 15 18 11 17 2 19 7	0.46

TABLE 5

The subarray having the highest amplitude is listed together with those subarrays that should be excluded in order to ensure maximum SNR for the particular beam location. The right column gives the expected gain by excluding these subarrays. For some of the beams there is a negative gain, which means that a loss in SNR would be encountered even by excluding only the subarray with the very lowest amplitude. The complete table is listed in Appendix 3.

It is found that for more than 90% of the DP beams, one or more subarrays could be excluded without decreasing the SNR of the array beam signal. For 70% of the beam locations three or more subarrays could be excluded. Only 9% of the beam signals would suffer a loss in SNR by excluding the poorest subarray. As could be expected from the previous discussions (see Example 2, 3 and 4, pp 6 and 7), there is seldom any significant gain in SNR by deleting some subarrays. Only for 2% of the DP beams is it possible to obtain an SNR gain of 0.4 dB or more, while for 18% of the cases a gain of 0.2 dB or more is possible

Both Table 2 and Table 5 show that the amplitude pattern may vary very drastically from one beam location to another. For example, subarray no. 22 has in average the smallest amplitudes but it is the very best subarray for beam location no. 11 and 13. Both beams are pointing towards southeastern Alaska. In general, we found that for any subarray there exists at least one beam location where it is the very best but also at least one location where it is the very poorest subarray. Fig. 4 shows the dependency of SNR of the array beam signal if a certain number of subarrays is permanently excluded. Because of the small subarray amplitude variations when averaging over all beam locations, a net loss would be observed even by excluding only the very worst subarray. Excluding only subarray no. 22 will, in this case, give a loss of 0.1 dB. If both subarrays no. 22 and no. 6 are excluded, the average loss would be 0.2 dB. Excluding half of the subarrays gives a loss of 2.1 dB in average. For some particular regions, the exclusion of some subarrays would of course have a much worse effect.

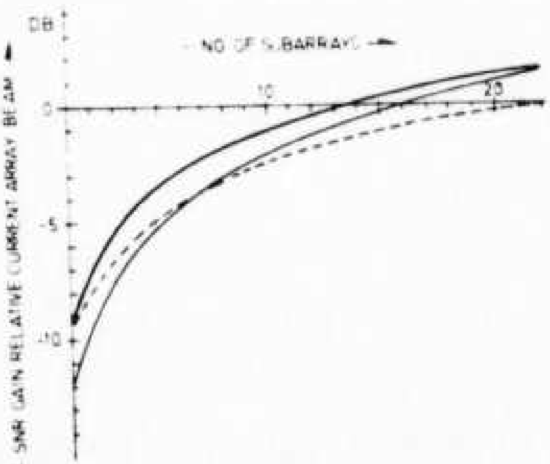

Fig. 4 Same as Fig. 2 but the data has been averaged over all beam locations. The array beam loss is seen to be 1.6 dB. Subarray no. 10 is best and is 9.2 dB below the full array beam signal. The broken line shows that if only the 11 best subarrays were used, the loss would be 2.1 dB.

SUBARRAY PRIORITY

If one or more of the subarrays at NORSAR were to be deleted, a priority scheme would be required in order to determine which subarrays should be suspended from operation and in which order. As demonstrated above, excluding any of the poorest subarrays would always give some loss in SNR on the array beam signal. In Table 6 is shown the loss for certain regions if the five poorest subarrays were excluded. Excluding only subarray no. 22 would give a loss considerably lower than the 0.2 dB expected from the $\sqrt{N}$ performance. However, for regions 1 and 3 the loss values are slightly above the theoretical values, because subarray no. 22 tends to have relatively high amplitudes for these regions. This is obvious from Table 7 where the subarray amplitude ranks are listed.

REGION	AREA OF COVERAGE	BEST	POOREST SUBARRAYS				
		13	22	06	15	19	14
1	Aleutians-Alaska	0.49	0.22	0.30	0.44	0.54	0.64
2	Western North America	0.12	0.15	0.25	0.43	0.59	0.78
3	Central America	0.29	0.22	0.44	0.47	0.66	0.94
4	Mid-Atlantic Ridge	0.11	0.15	0.23	0.39	0.74	0.89
5	Mediterranean-Middle East	0.10	0.22	0.47	0.77	0.79	0.97
6	Iran-Western Russia	0.31	0.10	0.24	0.39	0.60	0.74
7	Central Asia	0.38	0.04	0.14	0.34	0.49	0.67
8	Southern-Eastern Asia	0.41	0.05	0.10	0.30	0.50	0.78
9	Ryukuo-Philippines	0.44	0.06	0.09	0.24	0.56	0.63
10	Japan-Kamchatka	0.43	0.04	0.06	0.08	0.13	0.15
11	New Guinea-Hebrides	0.01	0.09	0.48	0.64	0.87	1.27
12	Fiji-Kermadec	0.01	0.12	0.57	0.63	0.96	1.35
13	South America	0.21	0.06	0.47	0.52	0.74	0.95
14	Distance Range 30°-180°	0.32	0.11	0.24	0.40	0.56	0.75
	Theoretical ($\sqrt{N}$) loss	0.20	0.20	0.41	0.64	0.87	1.12

TABLE 6

Expected SNR loss for region 1-14 (Table 4) if the in average best and 1 to 5 poorest subarrays were excluded, respectively. The bottom row gives the corresponding theoretical values.

REG	SUBARRAY RANKING																					
	01A 1	01B 2	02B 3	03B 4	04B 5	05B 6	06B 7	07B 8	01C 9	02C 10	03C 11	04C 12	05C 13	06C 14	07C 15	08C 16	09C 17	10C 18	11C 19	12C 20	13C 21	14C 22
14	10	16	4	7	14	21	11	15	5	6	2	3	1	18	20	9	17	13	19	12	8	22
1	12	22	5	19	15	18	11	21	4	7	3	2	1	17	14	9	13	20	16	6	8	10
2	5	9	10	1	16	21	18	4	7	17	2	22	20	11	12	6	8	3	13	15	19	14
3	10	6	4	3	2	12	1	19	22	20	18	16	5	8	21	17	11	15	14	7	13	9
4	21	8	12	7	11	22	5	4	13	1	10	20	19	18	16	9	17	2	3	6	14	15
5	8	15	2	17	3	5	11	14	9	19	21	6	18	13	4	1	12	20	22	10	16	7
6	6	9	14	2	7	16	8	22	21	20	17	1	3	18	15	13	5	4	10	12	11	19
7	19	3	8	7	13	17	22	15	4	5	1	6	2	12	10	16	20	18	14	9	11	21
8	12	21	7	10	11	22	19	17	2	3	4	5	1	8	6	14	15	9	18	16	13	20
9	11	16	9	14	13	22	15	7	4	8	3	1	2	17	10	12	19	20	6	18	5	21
10	10	7	1	9	15	21	8	13	2	4	6	5	3	20	22	18	11	12	16	14	17	19
11	13	5	10	9	19	3	15	8	20	18	1	22	21	4	14	7	6	12	11	16	2	17
12	12	17	9	7	16	2	15	8	22	20	1	18	21	5	19	4	10	11	6	14	3	13
13	9	16	19	14	10	3	1	5	17	15	21	18	8	12	22	2	7	6	11	4	13	20

TABLE 7

For each of the regions 1-14 defined in Table 4 the subarray amplitude ranks are listed. 1 means that it is the best subarray, while 22 means it is the poorest.

For regions 7, 8, 9 and 10 the loss values would be substantially lower than the $\sqrt{N}$ values. Excluding also subarray no. 6 will give losses higher than the theoretical for regions 3, 11, 12 and 13, while regions 8, 9, 10 would suffer only small SNR losses. Excluding the five poorest will give higher than theoretical loss values for regions 11 and 12, while region 10 would suffer only 0.15 dB loss.

Finally, Table 8 lists the subarrays which have the very highest and lowest amplitudes respectively for the 14 regions considered here. Also included is the loss encountered by excluding from one to five of the subarrays in the given regions.

DISCUSSION

By measuring the subarray and array beam amplitudes of a large number of events, a set of relative amplitude values has been established for most of the NORSAR Detection Processor beams. These are listed in Appendix 2. As a second result, these amplitudes have been used to establish which subarray should be masked for the different beams, and the possible gain in SNR by such masking. (For details, see Appendix 3.) Also for larger regions similar results have been obtained, e.g., see Tables 6, 7 and 8. In order to get these results some assumptions have been made which ought to be checked.

The first assumption was that the relative subarray amplitudes depend only on beam location; i.e., independent of event magnitude. Second, the original signal correlation matrix in eq. (4) is replaced by a matrix where all off-diagonal elements are identical. Finally, it has been assumed that the noise level is constant across the array, and that the noise is uncorrelated from one subarray to the other. This latest assumption is reasonable in view of previous NORSAR array studies, see f. ex. Felix et al (1972) and Harley (1972).

Region	Area of Coverage	Best		Poorest									
		No.	Loss by Excluding	No.					Loss by Excluding				
1	Aleutians-Alaska	13	0.47	2	8	18	4	6	0.04	0.11	0.18	0.24	0.31
2	Western North America	4	0.44	12	6	13	21	7	0.05	0.14	0.26	0.40	0.54
3	Central America	7	0.33	9	15	10	8	11	0.02	0.04	0.07	0.15	0.26
4	Mid-Atlantic Ridge	10	0.37	6	1	12	13	14	0.07	0.16	0.27	0.37	0.56
5	Mediterranean-Middle East	16	0.36	19	11	18	10	13	0.01	0.07	0.12	0.20	0.29
6	Iran-Western Russia	12	0.38	8	9	10	22	14	0.02	0.04	0.11	0.22	0.33
7	Central Asia	11	0.56	7	22	17	1	18	0.02	0.05	0.07	0.12	0.21
8	Southern-Eastern Asia	13	0.41	6	2	22	7	19	0.04	0.10	0.15	0.21	0.30
9	Ryukuo-Philippines	12	0.50	6	22	18	17	20	0.03	0.09	0.14	0.19	0.25
10	Japan-Kamchatka	3	0.51	15	6	14	22	16	0.03	0.05	0.06	0.10	0.12
11	New Guinea-Hebrides	11	0.42	12	13	9	5	10	-0.01	0.0	0.03	0.08	0.15
12	Fiji-Kermadec	11	0.57	9	13	10	15	12	0.01	0.02	0.02	0.06	0.11
13	South America	7	0.43	15	11	22	3	12	0.05	0.10	0.16	0.22	0.29
14	Distance Range 30°-180°	13	0.32	22	6	15	19	14	0.11	0.24	0.40	0.56	0.75
	Theoretical ($\sqrt{N}$) loss		0.20						0.20	0.41	0.64	0.97	1.12

TABLE 8

For each of the regions 1-14 (Table 4) is listed the subarray with highest amplitude and the loss in SNR expected for the particular region if this subarray is excluded. The five subarrays with lowest amplitude are then listed (starting with the very lowest) and the expected loss if one or more of these subarrays were excluded. The bottom row gives the corresponding theoretical values.

In the second case all the off-diagonal elements in the matrix R_S in eq. (4) were assumed equal to the average signal correlation value. This is surely an oversimplification as demonstrated in Figs. 5 and 6. The procedure here was first to measure SNR for the best subarray signal (as determined from Appendix 2), then to add the second best subarray and measure SNR again. The process was repeated until all 22 subarrays were included and thus corresponding to the full array beam. Figs. 5 and 6 show the results obtained for beam locations 36 and 63 using 10 different events in each case. All events are from 1974, i.e., none of them have been used in the previous data collection. The SNR variation is large when less than 10 subarrays are used in the beamforming process, but levels off rapidly as more subarrays are included. For example, the observed SNR variation was always less than 0.5 dB when the array beam is based on minimum 15 subarrays. The corresponding value for the case of 18 subarrays was 0.3 dB. These results have been interpreted as follows. The signal correlation matrix (eq. (4)) does not consist of only equal elements in the off-diagonal locations, thus the SNR of the summed traces is not a function of relative amplitude alone but also of the correlation between subarrays. When many instruments are used, say 15 or more, the effect of the scatter in the correlation values becomes less important, and for this case the assumption that all off-diagonal elements are equal is acceptable. When all 22 subarrays are used, the two different matrices have the same effect. We conclude, however, that in order to predict the gain in SNR during beamforming, the number of sensors should be at least 15.

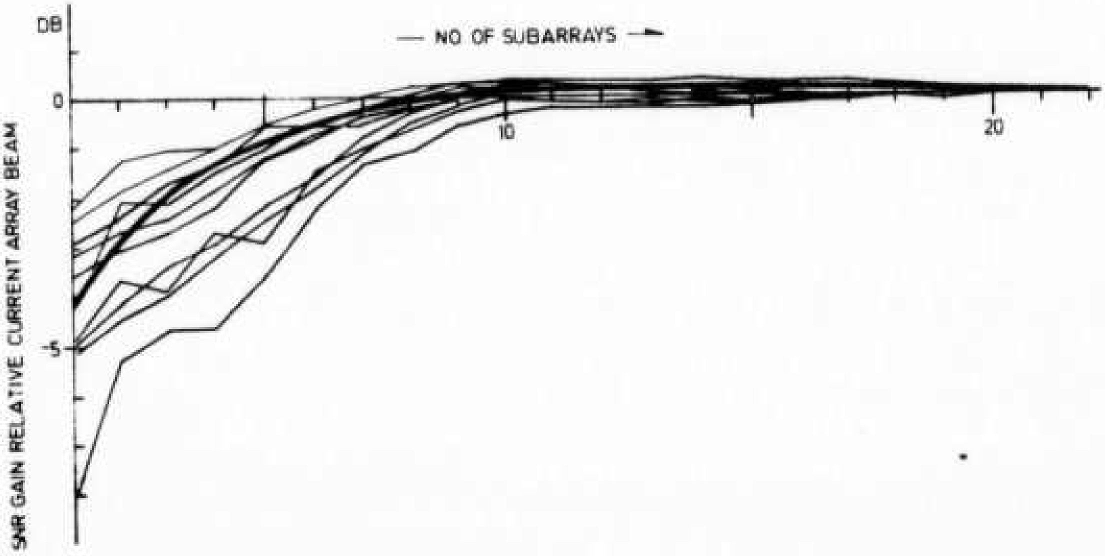

Fig. 5 Expected and obtained performance as a function of number of subarrays for DP beam no. 36. This beam is pointed towards 52N, 160E (off east coast of Kamchatka). The subarrays have been ranked according to their amplitude as listed in Appendix 2. The first one is the one with the highest amplitude, in this case no. 3. The thick line shows the expected performance from the observed amplitude pattern, and corresponds to the dotted line on Figs. 2,3, and 4. The thin lines give the observed values for 10 different events.

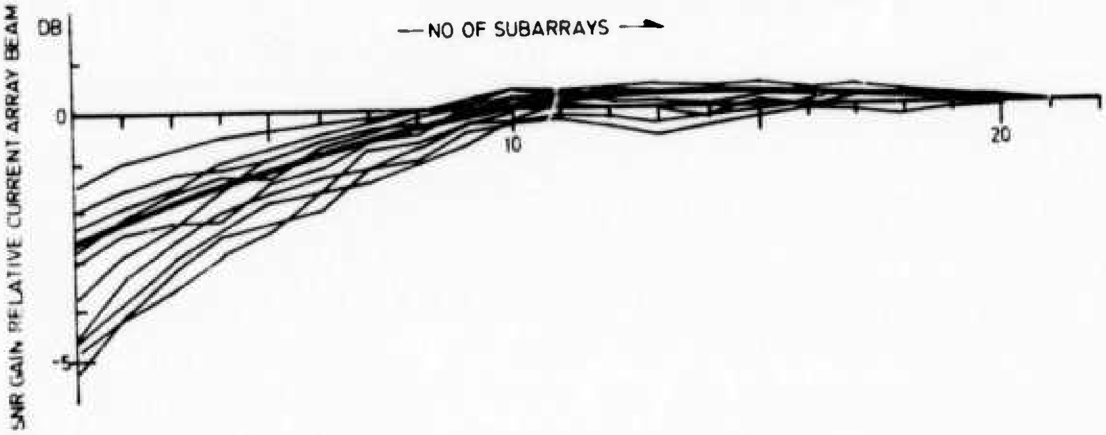

Fig. 6 Same as Fig. 5 for DP beam 63. This beam is pointed towards 43N, 147E (Kurile Islands).

The first assumption was that the relative subarray amplitudes for a particular beam location were independent of event magnitude. This is not necessarily true due to the joint effect of the spectrum scaling law (Aki, 1967) and a frequency dependent crust and upper mantle transfer function. For example, Husebye et al (1974) found that the body wave magnitude correction for conventional seismograph station could vary with event magnitude. To test whether such effects are significant in the amplitude variation across NORSAR, we designed the following experiment. Events corresponding to the most active beam locations (no. 36, 63, 115, 288 and 289) were separated in two equally large populations according to the magnitude. The H_0 hypothesis was that the relative amplitudes for these groups were identical. Using both the sign test and the Wilcoxon matched-pairs sign-rank test (Siegel, 1956), the results were that this hypothesis had to be rejected at the 0.05 level for all samples considered, thus supporting the hypothesis that the relative amplitudes may change as a function of magnitude. The data indicated that the large events had more extreme amplitude differences than the small events. However, by excluding the 3-5 weakest subarrays, we could no longer reject the H_0 hypothesis. The latter result seemingly contradicts the first one, but the proper explanation is as follows. For the groups of small magnitude events, the amplitudes of the weakest subarray signals are less than those of interfering noise wavelets, so the observational data for these particular subarrays becomes too erroneous. Thus, when removing the most unreliable observations, the H_0 hypothesis is to be accepted. Notice that the original signal records were bandpass filtered, 1.2-3.2 Hz, prior to the amplitude measurements. From the above results we conclude that the relative subarray amplitudes do not vary significantly with event magnitude for our type of data.

So far we have discussed the gain in SNR on the array beam level with respect to a 1.0-0.0 (one-zero) subarray weighting scheme. The reason for this is, of course, that the beamforming algorithm in the NORSAR on-line Detection Processor is limited to 1.0 or 0.0 weights. This implies a physical model where the subarray signals and noise levels are identical and the noise is uncorrelated between subarrays. The above assumptions are clearly not valid, so more flexible signal models would improve the gain in SNR of the array beam. This problem has recently been discussed by Christoffersson and Husebye (1974) who also described different weighting procedures which all are optimal under certain conditions. For example, using a model based on identical signals except for an unknown amplitude scaling factor, they obtain a relative gain in SNR of ca. 2.5 dB for events located in Japan and Central Asia. In order to illustrate this weighting technique, we consider a case with two subarrays having signal amplitudes $A_1 = 1$ and $A_2 = 2$. Straight summation of the two traces gives an SNR value of:

$$SNR_{AB} = \left[\frac{(1+2)^2}{1^2+1^2}\right]^{\frac{1}{2}} = 2.12$$

Assigning weights of 0.45 and 0.89 to the traces gives:

$$SNR_{WAB} = \left[\frac{(0.45\cdot 1+0.89\cdot 2)^2}{0.45^2+0.89^2}\right]^{\frac{1}{2}} = 2.24$$

That is, there is a relative gain in SNR of 0.46 dB by introducing individual subarray weights. These weights have the same general characteristics as the previously discussed 1.0-0.0 weights, which means that the gain is larger the more extreme the amplitude variations are. The procedure for calculating such signal amplitude weights is too complicated for on-line data processing, but instead

we may introduce prefixed subarray amplitude weights. This alternative is not optimum but still a relative gain in SNR is obtained as demonstrated in Table 9, where the weights and the gain values for the large regions (Table 4) are given. For the single beam locations an average gain of 0.72 dB is expected. For several of the areas with large amplitude values this gain is between 1.3 and 1.8 dB. As mentioned above, calculating individual amplitude weights for each event may give significantly better results, and this more sophisticated version of array beam forming is now an option in the NORSAR off-line Event Processor.

Finally, we want to forward some remarks on a mostly ignored problem when discussing the performance of an array, namely, that of signal-noise classification. The point here is that an array's ability to detect weak signals is almost exclusively tied to the relative gain in SNR on the array beam level, thus implying that this parameter is used as a diagnostic tool for signal-noise classification for wavelets triggering the array's detector. However, this decision rests with an analyst although the SNR-parameter is widely used for selection of wavelet detections for more refined analysis in the Event Processor (for details here, see Bungum et al, 1971, and Bungum and Husebye, 1974). In short, the analyst is reluctant to classify a detection as a seismic signal unless it is visible on at least a few subarray traces, has a 'proper' shape, etc. In other words, signal information extracted from the subarray beam is very important as a diagnostic tool for improved signal-noise classification. Recently, a purely statistical approach for solving this important problem has been forwarded by Fyen et al (1974) who claim that their test statistics may increase the number of NORSAR-reported events by ca. 10 per cent. The most powerful of the three statistics

REG	SUBARRAY																						GAIN
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	
1	20	31	14	28	24	28	20	28	14	15	11	10	5	26	24	18	22	28	26	15	17	18	48
2	18	19	20	8	23	27	24	17	18	24	13	32	25	22	23	18	19	14	23	23	24	23	25
3	17	15	12	11	11	18	10	28	36	34	26	21	12	16	36	22	18	21	21	16	20	17	61
4	27	20	22	19	21	29	15	15	22	11	20	26	26	25	23	20	24	14	14	19	23	23	21
5	17	22	10	25	11	14	21	21	18	26	30	15	26	21	12	5	21	30	36	20	24	15	51
6	16	19	21	11	18	24	19	33	33	28	24	9	13	25	23	20	15	13	19	20	20	26	39
7	28	14	16	16	21	25	32	23	15	15	4	15	10	21	19	25	30	25	22	17	20	30	46
8	21	30	15	19	20	31	29	25	8	11	13	13	7	16	14	24	24	18	26	25	22	30	52
9	21	25	19	25	24	30	25	16	10	16	10	5	7	27	21	23	27	28	13	27	11	28	57
10	18	17	6	18	25	29	18	22	8	13	14	14	9	29	30	28	18	19	27	23	27	29	53
11	21	15	18	17	28	10	22	15	30	26	8	35	33	13	22	15	15	20	19	24	8	26	55
12	21	26	16	15	25	8	24	16	32	31	3	27	32	13	29	11	17	19	14	24	9	23	66
13	19	25	28	22	19	10	8	14	25	25	30	27	18	20	30	9	15	15	20	13	22	29	45
14	21	22	18	20	22	26	22	22	18	19	16	18	14	23	24	21	23	22	24	22	21	27	8

TABLE 9

Subarray weights for optimum amplitude weighting for region 1-14 as defined in Table 4. The last column gives expected gain (dB·100) by such weighting. All values (weights and gain) are multiplied with 100.

considered is the one which utilized information on the amplitude distribution across the array. Thus, if any of the NORSAR subarrays are excluded permanently, this would adversely affect the signal-noise classification problem. The dominant factors are less extreme subarray amplitude variation, a reduced observation base for the test statistics of Fyen et al (1974), and a larger probability of positive interference of random noise wavelets. The latter effect would correspond to an increase in the number of so-called false alarms, i.e., noise wavelets triggering the array's event detector. We should here keep in mind that the above type of effects, which must be considered when assessing the performance of an array, are not directly tied to the relative gain in SNR on the array beam level.

CONCLUSION

In this study a detailed investigation is performed of the NORSAR subarray amplitude variation as a function of the array's Detection Processor beam locations and its effect on the signal-to-noise ratio of the array beam signal. Relevant results obtained are tabulated in Appendices 2 and 3 as a function of the array beam locations where data was available.

For several regions there is as much as 20 dB amplitude variations across the NORSAR array, but only exceptionally is a relative gain of more than 0.3 dB obtained in SNR by excluding one or more of the subarrays. Moreover, as the subarray amplitude pattern may change drastically within a small seismic region, any type of weighted array beamforming should be a function of the individual beam locations. Although some of the subarrays are bad for most of the seismic regions covered by NORSAR, they all have several regions where they add positively to the array beam. Therefore, in average there will always be some loss by excluding any of the subarrays consistently.

If some of the subarrays were to be masked permanently, we also have to consider other factors like the array's location capability, the effect of a reduced population in the signal-to-noise statistical test (Fyen et al, 1974), increase in the number of false alarms, etc. Finally, any type of subarray masking scheme corresponds essentially to a weighted NORSAR surveillance of the seismic active regions.

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APPENDIX 1

NORSAR array beam deployment (set 411), valid from 06 Feb 73.

Beam Set 411 (02/06/73) Part I

BEAM NO	UX (S/KM)	UY (S/KM)	PHASE	LAT	LON	REGION NUMBER AND NAME	
1	0.0[illegible]89930	-0.0913900	P	83N	7W	641	NORTH OF SVALBARD
2	-0.0638100	-0.0873700	P	73N	55E	648	NOVAYA ZEMLYA
3	0.0443600	-0.0689300	P	72N	74W	682	BAFFIN ISLAND REGION
4	0.0172400	-0.0659800	P	67N	137W	677	N. YUKON TERR.,CANADA
5	0.0117313	-0.0660309	P	65N	147W	676	ALASKA
6	0.0097600	-0.0650000	P	63N	151W	1	CENTRAL ALASKA
7	0.0[illegible]72200	-0.0668100	P	66N	155W	676	ALASKA
8	0.0117700	-0.0638100	P	61N	148W	2	SOUTHERN ALASKA
9	0.0[illegible]94000	-0.0634400	P	61N	152W	2	SOUTHERN ALASKA
10	0.0[illegible]05800	-0.0645159	P	65N	165W	676	ALASKA
11	0.0184800	-0.0599800	P	59N	137W	19	SOUTHEASTERN ALASKA
12	0.0133000	-0.0617500	P	60N	146W	2	SOUTHERN ALASKA
13	0.0155900	-0.0610500	P	60N	141W	19	SOUTHEASTERN ALASKA
14	0.0113200	-0.0518500	P	59N	149W	14	KENAI PENINSULA, ALASKA
15	0.0[illegible]75400	-0.0618300	P	58N	155W	12	ALASKA PENINSULA
16	0.0[illegible]54900	-0.0602300	P	57N	158W	12	ALASKA PENINSULA
17	0.0[illegible]93000	-0.0596800	P	57N	152W	13	KODIAK ISLAND REGION
18	0.0[illegible]67900	-0.0591600	P	55N	156W	17	SOUTH OF ALASKA
19	0.0[illegible]44000	-0.0584119	P	55N	160W	12	ALASKA PENINSULA
20	0.0019500	-0.0575700	P	54N	163W	10	UNIMAK ISLAND REGION
21	-0.0[illegible]14651	-0.0584119	P	55N	168W	9	FOX ISLANDS, ALEUTIANS
22	-0.0317300	-0.0581200	P	62N	143E	671	EASTERN SIBERIA
23	-0.0[illegible]09600	-0.0571200	P	53N	167W	9	FOX ISLANDS, ALEUTIANS
24	-0.0[illegible]38300	-0.0565900	P	52N	171W	9	FOX ISLANDS, ALEUTIANS
25	-0.0[illegible]58600	-0.0562600	P	52N	174W	7	ANDREANOF IS., ALEUTIANS
26	-0.0[illegible]84800	-0.0557100	P	52N	178W	7	ANDREANOF IS., ALEUTIANS
27	-0.0118300	-0.0549600	P	52N	177E	6	RAT ISLANDS, ALEUTIANS
28	-0.0184400	-0.0554300	P	55N	166E	4	KOMANDORSKY ISLANDS REG.
29	-0.0205266	-0.0558723	P	56N	162E	218	NEAR EAST COAST KAMCHATKA
30	0.0247000	-0.0545300	P	50N	130W	25	VANCOUVER ISLAND REGION
31	-0.0[illegible]76500	-0.0538300	P	50N	178W	7	ANDREANOF IS., ALEUTIANS
32	-0.0109500	-0.0539600	P	50N	179E	6	RAT ISLANDS, ALEUTIANS
33	-0.0136700	-0.0539700	P	51N	175E	6	RAT ISLANDS, ALEUTIANS
34	-0.0168600	-0.0545200	P	53N	169E	4	KOMANDORSKY ISLANDS REG.
35	-0.0151900	-0.0542300	P	52N	172E	5	NEAR ISLANDS, ALEUTIANS
36	-0.0219929	-0.0533326	P	52N	160E	219	OFF EAST COAST KAMCHATKA
37	-0.0207300	-0.0544200	P	54N	162E	218	NEAR EAST COAST KAMCHATKA
38	0.0382800	-0.0501600	P	45N	111W	456	MONTANA
39	0.0351916	-0.0507930	P	44N	116W	33	WESTERN IDAHO
40	0.0254800	-0.0511500	P	44N	129W	30	OFF COAST OF OREGON
41	0.0272200	-0.0503400	P	43N	126W	30	OFF COAST OF OREGON
42	-0.0741100	-0.0517800	P	50N	158E	222	KURILE ISLANDS REGION
43	-0.0263916	-0.0537930	P	50N	155E	221	KURILE ISLANDS
44	-0.0283900	-0.0519600	P	52N	152E	220	NORTHWEST OF KURILE IS.
45	-0.0699700	-0.0529800	P	67N	67E	335	URAL MOUNTAINS REGION
46	0.0372900	-0.0486100	P	42N	112W	457	EASTERN IDAHO
47	0.0308100	-0.0483500	P	40N	121W	36	NORTHERN CALIFORNIA
48	0.0278632	-0.0482533	P	41N	125W	34	OFF COAST OF NORTH CALIF.
49	0.0260400	-0.0483500	P	40N	128W	34	OFF COAST OF NORTH CALIF.
50	-0.0282200	-0.0488500	P	47N	154E	221	KURILE ISLANDS
51	-0.0312900	-0.0490500	P	49N	150E	220	NORTHWEST OF KURILE IS.
52	-0.0310900	-0.0473500	P	45N	152E	222	KURILE ISLANDS REGION
53	-0.0337200	-0.0474000	P	46N	148E	220	NORTHWEST OF KURILE IS.
54	0.0374000	-0.0462600	P	39N	112W	478	UTAH
55	0.0342800	-0.0461600	P	37N	116W	41	SOUTHERN NEVADA
56	0.0321200	-0.0468700	P	38N	119W	40	CALIFORNIA-NEVADA BORDER
57	0.0296800	-0.0454700	P	37N	122W	39	CENTRAL CALIFORNIA
58	-0.0322567	-0.0457137	P	44N	150E	222	KURILE ISLANDS REGION
59	-0.0366000	-0.0460200	P	46N	144E	663	SEA OF OKHOTSK
60	0.0423000	-0.0440100	P	40N	105W	479	COLORADO
61	0.0331700	-0.0437700	P	34N	117W	43	SOUTHERN CALIFORNIA
62	0.0307928	-0.0431740	P	34N	120W	43	SOUTHERN CALIFORNIA
63	-0.0343000	-0.0440100	P	43N	147E	221	KURILE ISLANDS
64	-0.0366555	-0.0431740	P	43N	144E	224	HOKKAIDO, JAPAN, REGION
65	-0.0395880	-0.0431740	P	44N	140E	223	EASTERN SEA OF JAPAN
66	-0.0567600	-0.0429400	P	56N	111E	327	LAKE BAIKAL REGION
67	-0.0891300	-0.0432500	P	64N	55E	335	URAL MOUNTAINS REGION
68	0.0347900	-0.0412400	P	31N	114W	49	GULF OF CALIFORNIA
69	0.0322590	-0.0406344	P	32N	117W	45	CALIFORNIA-MEXICO BORDER
70	-0.0362700	-0.0402000	P	39N	144E	229	OFF E COAST HONSHU,JAPAN
71	-0.0381218	-0.0406344	P	41N	142E	224	HOKKAIDO, JAPAN, REGION
72	-0.0410543	-0.0406344	P	42N	138E	223	EASTERN SEA OF JAPAN
73	0.0357200	-0.0378100	P	28N	112W	49	GULF OF CALIFORNIA
74	0.0337253	-0.0380947	P	29N	114W	48	BAJA CALIFORNIA
75	-0.0395880	-0.0380947	P	39N	140E	227	HONSHU, JAPAN
76	-0.0383200	-0.0377600	P	37N	142E	229	OFF E COAST HONSHU,JAPAN
77	-0.0446800	-0.0378100	P	41N	133E	663	SEA OF JAPAN
78	-0.0381218	-0.0355551	P	34N	142E	229	OFF E COAST HONSHU,JAPAN
79	-0.0410543	-0.0355551	P	36N	138E	227	HONSHU, JAPAN
80	-0.0400300	-0.0352000	P	34N	139E	230	NEAR S.COAST HONSHU,JAPAN

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BEAM NO	UX (S/KM)	UY (S/KM)	PHASE	LAT	LON	REGION NUMBER AND NAME	
81	-0.0428700	-0.0352100	P	37N	135E	660	SEA OF JAPAN
82	0.0523500	-0.0326000	P	37N	90W	485	EASTERN MISSOURI
83	0.0360600	-0.0341800	P	25N	110W	49	GULF OF CALIFORNIA
84	-0.0379400	-0.0338000	P	31N	142E	211	SOUTH OF HONSHU, JAPAN
85	-0.0377700	-0.0324700	P	29N	142E	211	SOUTH OF HONSHU, JAPAN
86	-0.0406400	-0.0334000	P	32N	138E	211	SOUTH OF HONSHU, JAPAN
87	-0.0425206	-0.0330154	P	34N	135E	233	NEAR S COAST OF S. HONSHU
88	0.0351900	-0.0305800	P	22N	109W	47	OFF [illegible].COAST OF BAJA CALIF.
89	-0.0339000	-0.0294900	P	18N	146E	216	MARIANA ISLANDS
90	-0.0355800	-0.0297600	P	23N	143E	213	VOLCANO ISLANDS REGION
91	-0.0394700	-0.0315200	P	29N	139E	211	SOUTH OF HONSHU, JAPAN
92	-0.0381218	-0.0304758	P	27N	140E	212	BONIN ISLANDS REGION
93	-0.0439500	-0.0309300	P	32N	132E	236	SHIKOKU, JAPAN
94	-0.0623600	-0.0313000	P	51N	101E	333	USSR-MONGOLIA BORDER REG.
95	0.0343600	-0.0283100	P	19N	109W	53	REVILLA GIGEDO ISLANDS
96	-0.0344800	-0.0278300	P	13N	145E	216	MARIANA ISLANDS
97	-0.0456800	-0.0269000	P	27N	129E	238	RYUKYU ISLANDS
98	-0.0449700	-0.0285400	P	29N	130E	238	RYUKYU ISLANDS
99	-0.0547600	-0.0272300	P	37N	115E	658	NORTHEASTERN CHINA
100	-0.0895300	-0.0272300	P	61N	56E	[illegible]35	URAL MOUNTAINS REGION
101	0.0381241	-0.0253965	P	19N	102W	57	MICHOACAN, MEXICO
102	0.0357900	-0.0266500	P	19N	106W	54	OFF COAST OF JALISCO, MEX
103	-0.0470900	-0.0254200	P	26N	126E	238	RYUKYU ISLANDS
104	0.0429200	-0.0219900	P	17N	96W	60	OAXACA, MEXICO
105	0.0396600	-0.0231500	P	17N	98W	59	GUERRERO, MEXICO
106	-0.0493600	-0.0217700	P	23N	121E	244	TAIWAN
107	-0.0486600	-0.0234100	P	24N	123E	246	SOUTHWESTERN RYUKYU IS.
108	-0.0729899	-0.0238100	P	54N	81E	326	CENTRAL RUSSIA
109	0.0915100	-0.0193800	P	58N	33W	402	NORTH ATLANTIC OCEAN
110	0.0442500	-0.0201100	P	16N	93W	61	CHIAPAS, MEXICO
111	0.0354900	-0.0207200	P	9N	103W	63	OFF COAST OF MEXICO
112	-0.0486000	-0.0203000	P	20N	121E	248	PHILIPPINE ISLANDS REGION
113	0.0425229	-0.0177776	P	14N	92W	69	NEAR COAST OF CHIAPAS,MEX
114	0.0353200	-0.0168300	P	3N	102W	693	E. CENTRAL PACIFIC OCEAN
115	-0.0450100	-0.0184400	P	11N	125E	251	SAMAR, PHILIPPINE ISLANDS
116	-0.0472800	-0.0183900	P	16N	121E	249	LUZON, PHILIPPINE ISLANDS
117	-0.0710800	-0.0166000	P	50N	79E	329	EASTERN KAZAKH SSR
118	0.0477700	-0.0162600	P	17N	87W	94	CARIBBEAN SEA
119	0.0440200	-0.0160700	P	13N	90W	71	NEAR COAST OF GUATEMALA
120	-0.0442800	-0.0163500	P	5N	126E	259	MINDANAO, PHILIPPINE IS.
121	-0.0462000	-0.0156000	P	13N	121E	250	MINDORO, PHILIPPINE IS.
122	-0.0586495	-0.0152379	P	27N	105E	664	EASTERN CHINA
123	-0.0615821	-0.0152379	P	33N	99E	325	TSINGHAI PROVINCE, CHINA
124	-0.0636700	-0.0155100	P	37N	96E	325	TSINGHAI PROVINCE, CHINA
125	-0.0674471	-0.0152379	P	43N	89E	332	NORTHERN SINKIANG PROV.
126	-0.0700800	-0.0150600	P	47N	82E	331	KAZAKH-SINKIANG BORDER
127	0.0452500	-0.0135000	P	12N	87W	74	NEAR COAST OF NICARAGUA
128	-0.0601158	-0.0126983	P	28N	100E	327	SZECHWAN PROVINCE, CHINA
129	-0.0630484	-0.0126983	P	33N	96E	325	TSINGHAI PROVINCE, CHINA
130	-0.0659809	-0.0126983	P	38N	91E	325	TSINGHAI PROVINCE, CHINA
131	-0.0689133	-0.0126983	P	42N	86E	332	NORTHERN SINKIANG PROV.
132	0.0453600	-0.0106700	P	10N	84W	78	COSTA RICA
133	0.0373800	-0.0098600	P	0N	91W	697	GALAPAGOS ISLANDS
134	-0.0453500	-0.0108600	P	0N	121E	265	NORTHERN CELEBES
135	-0.0586495	-0.0101586	P	23N	101E	318	YUNAN PROVINCE, CHINA
136	-0.0615821	-0.0101586	P	28N	96E	313	INDIA-CHINA BORDER REGION
137	-0.0645146	-0.0101586	P	33N	92E	325	TSINGHAI PROVINCE, CHINA
138	-0.0674471	-0.0101586	P	38N	87E	321	SOUTHERN SINKIANG PROV.
139	-0.0703797	-0.0101586	P	42N	83E	332	NORTHERN SINKIANG PROV.
140	0.0836599	-0.0080900	P	54N	36W	402	NORTH ATLANTIC OCEAN
141	0.0443300	-0.0077000	P	8N	82W	80	PANAMA-COSTA RICA BORDER
142	0.0396500	-0.0067200	P	3N	84W	76	OFF COAST OF CENT.AMERICA
143	-0.0601158	-0.0076190	P	23N	98E	297	BURMA-CHINA BORDER REGION
144	-0.0630484	-0.0076190	P	28N	93E	313	INDIA-CHINA BORDER REGION
145	-0.0659809	-0.0076190	P	33N	89E	306	TIBET
146	0.0566300	-0.0043200	P	20N	71W	88	DOMINICAN REPUBLIC REGION
147	0.0458900	-0.0043500	P	8N	78W	81	PANAMA
148	-0.0615821	-0.0050793	P	23N	94E	294	BURMA-INDIA BORDER REGION
149	-0.0645146	-0.0050793	P	28N	90E	306	TIBET
150	-0.0714559	-0.0063000	P	41N	79E	320	KIRGIZ-SINKIANG BORDER
151	0.0429500	-0.0030900	P	5N	78W	83	SOUTH OF PANAMA
152	0.0406900	-0.0026300	P	2N	79W	83	SOUTH OF PANAMA
153	0.0389900	-0.0031600	P	0N	81W	104	OFF COAST OF ECUADOR
154	0.0379200	-0.0016400	P	4S	81W	1[illegible]9	NEAR COAST OF N. PERU
155	-0.0601158	-0.0025397	P	17N	94E	296	BURMA
156	-0.0631900	-0.0032200	P	24N	91E	315	INDIA-BANGLADESH BORDER
157	-0.0662100	-0.0033300	P	30N	87E	306	TIBET
158	-0.0689133	-0.0025397	P	34N	83E	306	TIBET
159	-0.0718459	-0.0025397	P	39N	78E	321	SOUTHERN SINKIANG PROV.
160	0.0574100	-0.0011700	P	19N	68W	402	NORTH ATLANTIC OCEAN

(Sheet 2 of 4)

BEAM NO	UX (S/KM)	UY (S/KM)	PHASE	LAT	LON	REGION NUMBER AND NAME	
161	0.0435700	-0.0011600	P	5N	76W	103	COLOMBIA
162	0.0423400	0.0012700	P	3N	75W	103	COLOMBIA
163	0.0370100	0.0004700	P	7S	80W	108	OFF COAST OF N. PERU
164	0.0386000	-0.0002300	P	2S	78W	107	ECUADOR
165	-0.0481100	-0.0006000	P	6S	105E	276	SUNDA STRAIT
166	-0.0512500	0.0005400	P	2N	98E	706	NORTHERN SUMATRA
167	-0.0494300	0.0003400	P	2S	101E	274	SOUTHERN SUMATRA
168	-0.0543500	0.0007600	P	6N	96E	704	NICOBAR ISLANDS REGION
169	-0.0566000	0.0007900	P	9N	94E	704	NICOBAR ISLANDS REGION
170	-0.0586495	0.0	P	12N	93E	703	ANDAMAN ISLANDS REGION
171	-0.0666000	-0.0003000	P	28N	85E	310	NEPAL
172	-0.0735300	-0.0006100	P	40N	75E	320	KIRGIZ-SINKIANG BORDER
173	0.0578500	0.0020200	P	19N	65W	90	PUERTO RICO REGION
174	0.0496400	0.0020000	P	10N	71W	100	LAKE MARACAIBO
175	0.0467800	0.0017900	P	7N	73W	99	NORTHERN COLOMBIA
176	-0.0700300	0.0027200	P	32N	79E	304	KASHMIR-TIBET BORDER REG.
177	-0.0685900	0.0024400	P	29N	81E	310	NEPAL
178	-0.0718459	0.0025396	P	35N	77E	302	EASTERN KASHMIR
179	-0.0747785	0.0025396	P	41N	72E	716	KIRGIZ SSR
180	-0.0839100	0.0024000	P	52N	55E	335	URAL MOUNTAINS REGION
181	0.0578800	0.0052500	P	18N	63W	92	LEEWARD ISLANDS
182	0.0377900	0.0051300	P	7S	76W	111	NORTHERN PERU
183	-0.0733122	0.0050793	P	36N	74E	720	NORTHWESTERN KASHMIR
184	-0.0762448	0.0050793	P	41N	69E	716	KIRGIZ SSR
185	0.0655800	0.0076700	P	51N	30W	403	NORTH ATLANTIC RIDGE
186	0.0572300	0.0080400	P	16N	61W	92	LEEWARD ISLANDS
187	-0.0718459	0.0076189	P	32N	74E	711	SOUTHWESTERN KASHMIR
188	-0.0747785	0.0076189	P	37N	71E	717	AFGHANISTAN-USSR BORDER
189	0.0560800	0.0096800	P	13N	61W	95	WINDWARD ISLANDS
190	0.0533800	0.0090000	P	11N	62W	95	WINDWARD ISLANDS
191	0.0365400	0.0106300	P	10S	71W	112	PERU-BRAZIL BORDER REGION
192	-0.0743959	0.0099000	P	35N	70E	718	HINDU KUSH REGION
193	0.0352000	0.0132000	P	14S	69W	118	PERU-BOLIVIA BORDER REG.
194	-0.0760000	0.0127000	P	36N	67E	718	HINDU KUSH REGION
195	-0.0739000	0.0125000	P	33N	69E	709	AFGHANISTAN
196	-0.0654200	0.0157700	P	17N	74E	314	INDIA
197	-0.0725400	0.0149800	P	30N	69E	710	PAKISTAN
198	0.0333500	0.0175700	P	18S	64W	120	BOLIVIA
199	-0.0821500	0.0178700	P	44N	55E	336	WESTERN KAZAKH SSR
200	0.0674494	0.0203172	P	28N	45W	403	NORTH ATLANTIC RIDGE
201	0.0643150	0.0207600	P	25N	46W	403	NORTH ATLANTIC RIDGE
202	-0.0718300	0.0193300	P	27N	67E	710	PAKISTAN
203	-0.0863900	0.0210700	P	48N	48E	336	WESTERN KAZAKH SSR
204	0.0796000	0.0227600	P	46N	28W	403	NORTH ATLANTIC RIDGE
205	0.0700499	0.0229100	P	31N	41W	403	NORTH ATLANTIC RIDGE
206	0.0601181	0.0228568	P	21N	46W	403	NORTH ATLANTIC RIDGE
207	0.0574800	0.0232100	P	18N	47W	403	NORTH ATLANTIC RIDGE
208	-0.0772099	0.0232200	P	35N	59E	348	IRAN
209	0.0733145	0.0253965	P	36N	36W	403	NORTH ATLANTIC RIDGE
210	0.0536900	0.0264100	P	15N	46W	403	NORTH ATLANTIC RIDGE
211	-0.0402100	0.0263400	P	24S	70E	429	MID-INDIAN RISE
212	-0.0500800	0.0265900	P	5S	68E	426	CHAGOS ARCHIPELAGO REGION
213	-0.0703797	0.0253965	P	25N	63E	354	WESTERN PAKISTAN
214	0.0761000	0.0282800	P	41N	30W	404	AZORES ISLANDS REGION
215	0.0508500	0.0288400	P	12N	45W	403	NORTH ATLANTIC RIDGE
216	-0.0408900	0.0274600	P	20S	67E	429	MID-INDIAN RISE
217	-0.0434500	0.0274300	P	14S	66E	429	MID-INDIAN RISE
218	-0.0472900	0.0271500	P	9S	67E	429	MID-INDIAN RISE
219	-0.0546200	0.0273900	P	1N	66E	421	CARLSBERG RIDGE
220	-0.0724300	0.0270400	P	27N	60E	353	SOUTHERN IRAN
221	-0.0785900	0.0268100	P	36N	55E	348	IRAN
222	-0.0573700	0.0317300	P	6N	61E	421	CARLSBERG RIDGE
223	-0.0725000	0.0302000	P	27N	57E	353	SOUTHERN IRAN
224	-0.0755900	0.0312200	P	32N	54E	348	IRAN
725	0.0483880	0.0330154	P	10N	42W	403	NORTH ATLANTIC RIDGE
226	-0.0725000	0.0324000	P	28N	55E	353	SOUTHERN IRAN
227	-0.0773000	0.0335000	P	36N	50E	348	IRAN
228	-0.0807800	0.0329800	P	43N	45E	337	EASTERN CAUCASUS
229	-0.0589800	0.0350300	P	10N	57E	421	CARLSBERG RIDGE
230	-0.0622200	0.0349200	P	15N	56E	417	ARABIAN SEA
231	-0.0732000	0.0364000	P	31N	50E	348	IRAN
232	-0.0721100	0.0346400	P	28N	53E	353	SOUTHERN IRAN
233	-0.0609100	0.0386700	P	15N	53E	417	ARABIAN SEA
234	-0.0760900	0.0392000	P	38N	45E	344	N.W. IRAN-USSR BORDER REG
235	0.0448700	0.0397200	P	8N	37W	406	C. MID-ATLANTIC RIDGE
236	-0.0732000	0.0406000	P	34N	46E	347	WESTERN IRAN
237	0.0659500	0.0419900	P	37N	25W	405	AZORES ISLANDS
238	0.0414900	0.0439400	P	4N	33W	406	C. MID-ATLANTIC RIDGE
239	-0.0577300	0.0428700	P	13N	49E	415	EASTERN GULF OF ADEN
240	-0.0736000	0.0429700	P	39N	41E	366	TURKEY

BEAM NO	UX (S/KM)	UY (S/KM)	PHASE	LAT	LON	REGION NUMBER	AND NAME
241	0.0361200	0.0459100	P	1N	30W	406	C. MID-ATLANTIC RIDGE
242	0.0110600	0.0455900	P	23S	13W	410	SOUTH ATLANTIC RIDGE
243	-0.0188100	0.0454100	P	26S	28E	584	REPUBLIC OF SOUTH AFRICA
244	0.0325800	0.0493900	P	1N	26W	406	C. MID-ATLANTIC RIDGE
245	0.0132100	0.0485400	P	18S	13W	410	SOUTH ATLANTIC RIDGE
246	0.0293265	0.0507930	P	1S	24W	406	C. MID-ATLANTIC RIDGE
247	0.0162300	0.0510100	P	13S	14W	410	SOUTH ATLANTIC RIDGE
248	-0.0222700	0.0506600	P	17S	29E	580	RHODESIA
249	-0.0293800	0.0508200	P	11S	34E	577	MALAWI
250	-0.0516000	0.0501200	P	12N	43E	555	WESTERN ARABIAN PENINSULA
251	-0.0330300	0.0537200	P	4S	35E	573	TANZANIA
252	-0.0459100	0.0538200	P	10N	39E	558	ETHIOPIA
253	-0.0655100	0.0539800	P	37N	36E	366	TURKEY
254	0.0258300	0.0550400	P	0N	18W	406	C. MID-ATLANTIC RIDGE
255	0.0185000	0.0547000	P	7S	13W	408	ASCENSION ISLAND REGION
256	-0.0270400	0.0562700	P	7S	30E	572	LAKE TANGANYIKA REGION
257	-0.0528700	0.0555800	P	20N	39E	555	WESTERN ARABIAN PENINSULA
258	0.0211600	0.0573100	P	2S	13W	407	NORTH OF ASCENSION ISLAND
259	-0.0298600	0.0596300	P	1N	30E	568	UGANDA
260	-0.0687600	0.0590700	P	41N	33E	366	TURKEY
261	-0.0811900	0.0575800	P	45N	34E	361	CRIMEA REGION
262	-0.0581000	0.0616500	P	35N	33E	372	CYPRUS
263	-0.0512400	0.0632100	P	28N	33E	553	UNITED ARAB REPUBLIC
264	0.0441000	0.0659200	P	36N	11W	402	NORTH ATLANTIC OCEAN
265	-0.0513182	0.0685706	P	37N	29E	366	TURKEY
266	-0.0452900	0.0716799	P	35N	27E	369	DODECANESE ISLANDS
267	-0.0561400	0.0702200	P	39N	28E	366	TURKEY
268	0.0306400	0.0755900	P	36N	4W	385	STRAITS OF GIBRALTER
269	-0.0381218	0.0761895	P	35N	24E	370	CRETE
270	0.0110300	0.0846300	P	36N	5E	396	ALGERIA
271	-0.0082600	0.1054600	P	44N	12E	545	NORTHERN ITALY
272	-0.0166900	0.0918900	P	39N	15E	390	SOUTHERN ITALY
273	-0.0295100	0.1043299	P	43N	17E	383	YUGOSLAVIA
274	-0.0337230	0.0787292	P	36N	22E	368	SOUTHERN GREECE
275	-0.0336800	0.0836400	P	38N	21E	364	GREECE
276	-0.0373900	0.0926400	P	41N	20E	391	ALBANIA
277	-0.0440400	0.0806600	P	39N	24E	365	AEGEAN SEA
278	-0.0731699	0.0846900	P	46N	27E	358	RUMANIA
279	-0.0540100	-0.0474300	PP	14N	145E	216	MARIANA ISLANDS
280	-0.0433800	-0.0457300	PP	9S	159E	193	SOLOMON ISLANDS
281	-0.0493300	-0.0420300	PP	5S	152E	192	NEW BRITAIN REGION
282	-0.0677900	-0.0285600	PP	20N	121E	248	PHILIPPINE ISLANDS REGION
283	-0.0615821	-0.0253965	PP	2S	132E	196	WEST NEW GUINEA REGION
284	-0.0653400	-0.0242600	PP	5N	126E	259	MINDANAO, PHILIPPINE IS.
285	-0.0684900	-0.0244300	PP	13N	121E	250	MINDORO, PHILIPPINE IS.
286	-0.0101900	-0.0285900	PKP	24S	176W	171	SOUTH OF FIJI ISLANDS
287	-0.0136800	-0.0286900	PKP	25S	180W	171	SOUTH OF FIJI ISLANDS
288	-0.0118800	-0.0250200	PKP	28S	177W	177	KERMADEC ISLANDS REGION
289	-0.0135100	-0.0225700	PKP	32S	179W	179	SOUTH OF KERMADEC ISLANDS
290	-0.0170200	-0.0165400	PKP	14S	167E	186	NEW HEBRIDES ISLANDS
291	-0.0081300	-0.0153900	PKP	16S	174W	173	TONGA ISLANDS
292	-0.0104500	-0.0154600	PKP	19S	179W	181	FIJI ISLANDS REGION
293	-0.0153400	-0.0160500	PKP	23S	172E	189	LOYALTY ISLANDS REGION
294	-0.0189700	-0.0139700	PKP	8S	158E	193	SOLOMON ISLANDS
295	-0.0201300	-0.0122100	PKP	5S	152E	192	NEW BRITAIN REGION
296	-0.0241300	-0.0064500	PKP	9S	130E	290	TIMOR SEA
297	0.0112900	-0.0030500	PKP	23S	113W	685	EASTER ISLAND REGION
298	0.0116700	0.0025300	PKP	36S	103W	692	SOUTHERN PACIFIC OCEAN
299	0.0108500	0.0074100	PKP	42S	90W	692	SOUTHERN PACIFIC OCEAN
300	0.0105400	0.0095400	PKP	30S	71W	135	NEAR COAST OF C. CHILE
301	0.0199200	0.0104600	PKP	37S	72W	136	CENTRAL CHILE
302	0.0193200	0.0114700	PKP	46S	75W	144	NEAR COAST OF S. CHILE
303	-0.0013500	0.0220600	PKP	59S	26W	153	SOUTH SANDWICH IS. REGION
304	-0.0001200	0.0196000	PKP	56S	30W	153	SOUTH SANDWICH IS. REGION
305	-0.0152000	0.0209000	PKP	55S	2W	410	SOUTH ATLANTIC RIDGE
306	-0.0106000	0.0205700	PKP	54S	27E	430	SOUTH OF AFRICA
307	-0.0330600	-0.0060300	PKKP	16S	73W	115	NEAR COAST OF PERU
308	0.0216200	0.0132000	PKKP	6S	131E	281	TANIMBAR ISLANDS REGION
309	0.0180800	0.0116800	PKKP	11N	121E	254	PANAY, PHILIPPINE ISLANDS
310	0.0183900	0.0196500	PKKP	4S	142E	202	NEW GUINEA
311	0.0187900	0.0238300	PKKP	7S	148E	207	EAST NEW GUINEA REGION
312	0.0159600	0.0278000	PKKP	7S	154E	193	SOLOMON ISLANDS
313	-0.0197400	-0.0391300	SKP	19S	175W	173	TONGA ISLANDS
314	-0.0134400	-0.0381900	SKP	19S	179W	181	FIJI ISLANDS REGION
315	-0.0258400	-0.0332200	SKP	18S	168E	186	NEW HEBRIDES ISLANDS
316	-0.0198000	-0.0234800	SKP	22S	170E	189	LOYALTY ISLANDS REGION
317	-0.0157900	-0.0359500	PCP	52N	174W	7	ANDREANOF IS., ALEUTIANS
318	-0.0192600	-0.0339000	PCP	51N	158E	218	NEAR EAST COAST KAMCHATKA

APPENDIX 2

Average subarray and array beam (AB) amplitudes (in dB down) relative to the best subarray for selected NORSAR Detection Processor (DP) beams. The different beam locations are listed in Appendix 1.

BEAM NO.	SUBARRAY NUMBER																					AB
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	
6	3	9	5	10	13	10	3	4	5	12	9	2	0	9	5	8	8	10	8	8	8	[illegible]	8
9	2	6	3	9	11	8	1	5	4	8	6	3	1	12	5	6	7	10	12	5	5	4	7
11	1	7	5	9	6	9	7	5	5	5	4	5	4	12	10	4	7	8	7	5	9	0	8
12	0	5	6	12	10	6	2	6	8	7	8	4	6	12	8	5	6	12	11	4	8	1	7
13	3	9	6	13	8	9	9	6	7	8	7	8	5	12	12	7	7	9	8	5	10	0	9
15	1	7	6	11	11	7	3	3	8	6	7	4	2	9	2	3	7	10	10	6	7	4	7
16	3	10	8	11	11	11	0	6	3	4	5	5	4	7	6	3	4	7	5	10	7	6	8
17	0	8	8	17	10	7	6	8	8	6	7	4	2	9	3	2	8	8	12	8		6	8
20	6	6	7	9	6	11	1	4	4	5	2	5	4	8	8	5	6	8	3	6	4	4	9
21	13	14	6	9	10	14	5	9	6	6	[illegible]	2	[illegible]	8	8	4	7	6	3	3	6	6	7
23	14	13	7	13	13	15	4	9	7	8	0	3	0	10	8	5	7	8	3	5	9	5	8
24	14	14	5	12	12	13	5	9	8	7	0	2	1	11	8	5	6	6	2	4	8	7	8
25	8	15	2	11	9	12	11	13	2	2	1	3	3	10	9	4	11	8	6	1	4	5	9
26	11	15	2	14	6	13	14	15	5	5	5	5	1	11	9	10	11	12	15	2	6	6	9
27	9	11	3	8	7	8	12	13	1	2	3	4	1	10	11	11	11	14	12	3	3	6	8
29	5	8	0	2	10	10	9	15	5	7	3	8	6	11	14	11	3	13	15	11	5	9	9
31	13	15	4	10	6	13	14	15	3	5	6	6	1	11	9	8	10	13	13	3	6	7	10
32	9	13	4	10	5	10	12	16	3	8	3	4	0	8	7	6	8	13	11	4	5		8
33	8	10	3	6	4	8	14	14	3	3	4	2	1	10	8	8	6	13	13	4	4	15	9
34	6	11	0	2	9	9	13	19	3	0	3	5	4	10	14	9	8	14	17	9	6	9	9
35	8	13	1	4	4	5	10	15	3	1	2	1	1	9	11	8	9	14	14	6	3	7	7
36	5	9	0	3	12	12	8	14	3	6	4	8	9	13	14	13	2	10	16	13	7	11	9
37	5	9	0	1	10	10	8	18	4	5	4	9	7	14	16	12	0	9	16	13	6	11	8
42	7	7	1	5	11	11	6	10	3	5	2	5	6	11	9	10	2	9	13	12	8	11	9
43	7	7	1	6	10	12	4	10	2	4	4	5	5	11	9	10	1	6	12	11	7	9	8
48	3	4	8	4	9	6	7	3	4	6	2	11	10	6	8	9	8	0	9	6	10	8	8
50	8	11	0	3	9	12	5	11	3	6	5	6	2	11	9	10	5	7	11	12	12	12	8
52	10	13	1	6	9	14	9	13	8	9	5	5	0	10	11	11	11	9	14	15	16	17	11
53	8	8	0	8	11	13	6	12	7	10	7	5	2	12	15	14	12	6	13	13	15	17	11
55	14	10	9	0	11	18	16	10		15	6	16	16	8	10	11	15	10	13	15	14	18	12
56	9	7	8	1	6	7	11	7	8	9	1	13	6	0	5	7	5	3	12	8	8		9
58	9	10	0	8	10	14	8	14	9	10	8	4	2	13	16	14	13	7	14	14	17	18	11
60	8	6	9	0	15	5	12	2	4	10	2	6	2	1	3	8	6	11	14	8	10	11	9
62	8	7	8	0	12	16	12	12	9		5	18	15	10	8	7	11	8	9	15	15	17	10
63	8	8	1	9	12	15	7	12	7	8	7	6	4	15	17	14	14	5	13	12	16	15	11
64	7	4	0	8	12	15	6	8	3	6	3	5	3	14	16	14	11	3	12	9	16	11	9
65	8	1	2	10	9	14	8	3	0	2	1	7	2	13	12	14	9	2	8	2	8	4	8
70	8	4	2	9	10	13	7	4	1	1	4	4	3	12	12	9	9	5	9	7	14	12	8
71	8	4	3	10	11	14	8	5	0	4	4	5	3	12	12	12	10	5	10	6	13	11	9
73	6	6	6	0	8	9	7	4	6	10	7	12		6	6	3	1	2	8	8	6	8	8
74	8	8	7	0	10	8	7	8	8	8	6	8	9	8	10	7	6	4	7	8	6		10
75	9	6	6	11	11	14	8	7	0	4	9	6	2	14	12	12	9	7	10	7	15	12	9
76	9	6	7	11	11	15	8	6	1	5	9	6	1	15	12	13	10	9	10	8	16	14	9
77	16	9	2	3	7	12	15	9	5	11	7	7	0	12	5	15	9	12	14	9		14	12
78	9	7	7	12	10	13	9	6	0	3	9	5	3	14	12	12	10	12	11	10	13	14	10
79	16	12	10	15	16	16	12	9	0	5	14	6	2	18	15	17	13	14	12	9	15	18	12
80	12	8	9	13	10	15	10	7	0	4	10	7	3	15	13	13	12	13	12	11	13	15	11

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BEAM NO.	SUBARRAY NUMBER																						AB
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	
81	14	13	7	9	16	21	15	10	5	10	7	5	0	14	17	15	16	12	12	13	15		14
83	7	4	8	0	8	7	5	2	7	9	6	13	9	10	5	4	1	1	2	7	2		8
84	9	9	7	11	8	12	8	5	0	2	7	6	3	13	12	13	12	12	11	10	12	13	10
86	13	10	10	14	9	10	11	7	0	6	10	5	1	14	10	13	11	13	10	11	13	18	11
87	13	9	8	12	12	14	10	8	3	8	6	4	0	15	13	17	14	17	8	12	11	16	11
89	8	8	10	11	7	10	11	[illegible]	5	8	8	7	11	8	7	8	8	7	7	11	6	12	11
90	6	7	8	13	7	14	9	1	1	3	4	4	7	8	9	10	10	5	5	12	8	12	9
91	7	6	5	13	7	13	10	6	2	3	7	2	0	13	11	14	12	11	10	12	14	18	9
92	7	7	4	10	6	10	8	2	1	3	7	1	2	9	11	11	13	9	7	12	10	13	8
93	12	8	4	7	12	17	11	5	2	6	4	0	1	14	12	13	8	15	6	8	6	14	9
95	9	2	3	0	1	11	3	7	11	7	7	10	8	9	11	6	4	1	4	9	5	5	7
97	10	8	5	12	11	13	12	6	0	5	3	3	1	12	9	11	9	13	6	10	2	10	9
98	8	6	6	9	9	12	9	3	1	4	4	2	3	11	10	10	8	12	4	10	6	13	9
101	9	8	2	3	3	7	2	6	12	14	8	10	4	13	8	6	4	3	1	5	2	4	7
102	10	3	3	2	1	9	3	8	10	10	7	12	7	9	9	5	5	1	1	10	3	3	7
103	8	12	5	10	9	11	10	6	1	10	4	4	0	9	7	10	9	11	4	9	1	11	9
104	0	4	3	3	6	2	3	8	11	9	6	4	1	1	13	8	7	10	7	3	8	7	6
105	3	2	3	2	0	1	2	10	9	13	5	4	1	3	7	6	5	6	6	[illegible]	2	4	5
106	9	11	5	11	11	11	11	6	4	6	3	[illegible]	1	11	8	10	12	12	8	15	3	12	10
107	9	13	5	11	11	13	10	7	3	7	3	2	[illegible]	10	6	10	11	15	6	11	2	12	9
110	3	5	7	8	4	5	5	10	12	8	9	3	2	2	11	8	7	7	9	2	8	5	9
112	5	12	7	9	9	10	7	4	2	7	4	1	4	10	6	5	10	7	3	8	2	10	8
113	1	2	1	2	2	5	2	8	9	10	5	1	2	0	11	7	5	11	13	7	14		5
115	4	11	9	9	7	9	6	5	3	3	3	3	6	10	5	3	11	3	2	8	3	10	8
116	9	13	11	14	11	14	12	7	5	6	3	0	4	14	9	7	12	11	7	13	4	12	11
119	3	8	5	6	6	3	4	9	9	9	11	5	4	0	10	6	4	10	7	1	5	6	9
120	7	12	10	11	9	12	7	5	4	3	3	4	8	11	6	6	12	5	3	7	0	7	9
121	5	10	10	10	9	10	8	4	3	4	4	3	8	11	7	5	12	7	3	8	2	10	9
122	9	13	4	8	6	11	9	9	0	3	8	7	6	4	4	7	3	6	6	12	7	10	8
123	7	12	3	6	5	12	11	10	0	2	9	5	6	1	3	7	6	3	3	12	8	8	7
124	6	8	0	5	3	12	11	8	6	8	7	2	6	1	5	8	9	4	8	12	9	8	8
125	7	7	2	6	4	11	16	10	9	9	6	5	4	0	7	9	13	6	7	12	9	9	9
126	5	6	6	3	8	9	10	6	10	7	5	7	7	2	5	9	11	7	13	12	9	11	12
127	0	5	8	10	10	4	6	9	13	9	10	10	2	2		7	5	5	8	2	9		8
129	7	11	0	4	7	13	9	8	2	5	7	6	2	3	2	8	7	8	8	9	6		9
131	5	6		4	8	8	6	7	6	5	4	2	0	4	7	3	8	8	8	7	4	9	8
132	2	2	6	7	9	8	4	5	9	5	9	5	2	4	13	4	9	8	7	4	7	4	8
134	8	10	15	14	8	7	6	6	4	3	5	10	11	8	5	3	10	8	4	3	0	10	8
135	6	9	5	3	3	9	2	5	3	1	4	3	3	5	0	9	8	13	7	7	4		6
136	9	9	4	7	10	10	5	7	2	0	7	5	5	5	3	9	7	7	9	12	8	8	10
137	7	10	2	7	5	10	8	7	1	0	4	3	0	2	2	5	5	6	7	9	6	6	7
138	1	9	6	8	4	12	16	9	3	4	5	1	1	4	4	5	7	0	3	6	6	10	5
139	3	7	3	6	6	10	13	7	2	2	1	1	0	4	7	7	11	7	7	6	5	4	7
140	0	3	3		5	6	3	4	7	2	7	4	3	5	8	5	7	5	11	7	4	3	9
141	6	6	3	9	7	8	8	7	12	10	4	6	0	1	11	7	6	7	10	6	12		10
142	8	3	5	5	7	5	2	4	3	3	8	3	0	5	9	3	3	0	5		8	6	5
143	5	10	7	11	9	9	6	9	2	2	2	5	8	5	0	8	4	11	11	14	7		9

BEAM NO.	SUBARRAY NUMBER 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	AB
144	8	13	9	13	8	14	6	13	2	5	5	8	7	8	0	4	5	10	11	18	4		9
145	5	7	4	3	7	11	11	9	4	1	5	3	1	4	5	9	7	4	11	8	8	10	9
148	6	14	13	7	6	9	2	9	1	4	3	10	3	5	1	6	4	7	11	15	4	7	8
149	6	9	7	4	3	10	2	9	1	3	3	5	0	3	1	3	2	2	8	8	6		6
150	5	11	8	23	7	9	13	8	3	5	2	2	0	3	6	11	11	9	13	6	8	11	8
151	5	6	12	8	9	5	3	8	11	9	13	5	3	7	12	5	9	10	9	1	7	9	8
152	10	5	9	7	10	2	1	4	[illegible]	6	[illegible]	6	7	5	[illegible]	[illegible]	4	8	12	1	10	13	7
155	6	12	7	5	4	7	0	7	2	3	1	8	2	5	4	4	7	6	10	6	3	7	7
157	7	9	5	0	9	12	9	8	2	3	3	8	0	9	7	8	5	3	6	10	7	10	8
159	4	10	9	9	5	10	10	7	3	5	2	2	0	3	8	7	9	4	9	2	6	12	8
161	6	8	9	10	8	3	3	9	10	8	13	5	3	8	10	2	8	9	11	1	7	10	9
162	5	7	11	7	6	1	2	6	11	10	11	5	4	7	8	3	9	8	9	1	7	10	9
164	11	8	12	10	8	5	0	7	11	7	11	12	8	9	15	6	7	7	4	2	14	11	9
165	8	6	10	6	5	9	6	7	9	5	7	8	7	5	6	3	10	10	11	2	2	10	10
166	10	11	10	4	5	5	6	6	7	6	5	6	1	3	2	2	6	8	10	0	3	8	7
167	10	6	12	9	5	7	5	6	7	5	8	8	5	4	6	3	13	9	12	0	2	9	8
168	11	6	9	5	5	5	3	5	6	10	3	6	1	6	2	3	9	10	10	2	3	6	8
169	9	11	10	5	5	4	5	7	8	10	4	7	0	3	3	2	8	14	13	5	5	7	7
170	8	10	9	7	5	5	4	10	7	10	6	10	0	3	1	2	5	13	13	11	7	7	9
171	12	13	9	5	9	9	12	11	4	0	3	7	2	10	9	11	12	4	10	4	10	11	10
172	8	10	5	1	12	10	15	5	5	7	2	5	5	10	9	11	15	9	12	4	12	11	10
175	1	1	10	7	4	5	3	6	9	5	10	3	9	7	8	2	11	10	11	8	6	10	8
177	9	9	4	6	6	6	12	10	0	3	3	5	0	10	9	11	9	9	11	10	6	13	10
178	9	8	6	2	10	6	12	6	3	7	2	3	0	11	8	9	13	6	9	4	8	12	9
179	12	9	7	5	15	11	15	8	4	8	0	8	6	13	9	15	16	11	11	4	12	15	10
181	7	9	10	4	4	13	2	9	10	10	5	6	8	6	10	9	7	8	9	7	8	[illegible]	7
182	5	9	8	11	7	6	1	3	11	9	10	9	6	8	8	3	4	2	6	5	8	10	8
183	15	6	5	5	10	12	14	9	4	4	1	7	4	14	7	14	15	13	8	4	11	15	10
184	16	7	6	4	13	9	19	9	5	9	0	11	5	14	4	12	13	14	17	6	11	15	11
186	3	0	1	7	1	6	4	7	9	6	3	2	6	3	9	4	11	0	6	4	8	2	5
187	11	3	5	3	8	8	10	6	6	4	2	2	1	11	6	11	13	7	4	2	8	15	9
188	14	6	8	8	15	14	16	11	5	5	0	11	7	16	9	15	17	16	12	5	11	14	11
189	2	2	5	7	4	9	8	10	8	5	0	6	4	5	10	10	16	1	6	4	5		8
190	7	4	11	8	5	14	13	11	13	9	8	0	6	5	9	7	14	7	12	10	11	10	10
191	3	8	10	7	7	4	3	0	6	6	6	8	6	8	8	5	6	6	12	6	6	11	8
192	13	6	9	9	11	12	16	12	6	7	0	9	4	14	10	11	13	15-	12	9	9	14	11
195	17	4	12	12	7	11	15	12	5	7	0	6	3	8	9	10	14	18	11	9	6	16	10
197	10	2	6	8	4	6	6	9	4	5	0	6	4	6	9	5	9	5	3	5	2	8	8
198	7	12	16	9	5	3	4	2	5	9	17	17	15	11	16	5	2	0	5	8	1		9
202	17	3	7	8	3	3	7	13	9	5	3	5	8	3	9	6	3	3	0	8	6		8
203	3	3	5	5	1	6	9	8	10	2	0	1	2	3	6	3	8	11	7	13	11	6	12
210	15	12	12	13	8	10	6	6	10	8	13	16	14	8	12	9	11	0	9	12	13	8	10
213	7	5	9	2	0	4	5	4	11	8	8	6	2	1	5	2	1	2	2	8	5	11	6
215	13	7	11	5	5	9	6	5	9	6	11	11	13	8	12	7	8	0	9	12	12	6	11
220	5	6	6	1	4	5	6	9	11	8	6	3	3	4	7	3	3	3	5	6	6	8	7
221	6	9	10	4	8	10	7	14	10	8	3	0	4	9	7	6	6	5	9	6	9	8	9
222	12	4	9	11	2	3	8	7	12	16	14	10	9	10	5	12	0	3	6	6	4	12	14

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BEAM NO.	SUBARRAY NUMBER																						AB
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	
223	4	6	6	0	7	6	5	14	9	13	10	1	0	6	5	6	6	6	6	5	10	6	9
224	3	5	5	1	7	9	5	12	10	10	9	3	2	9	9	9	7	8	7	6	6	7	9
226	7	8	4	1	7	6	4	11	14	12	9	1	1	11	11	8	6	4	5	5	5	9	7
227	5	3	2	3	5	15	5	15	13	11	9	2	1	10	0	3	6	9	9	10	9	8	9
229	7	5	13	9	3	10	6	1	13	13	16	10	7	5	8	0	1	4	4	6	6	1	9
230	8	9	15	8	2	11	5	2	14	17	13	9	7	4	8	2	0	3	2	14	7	4	9
231	7	8	10	8	10	11	9	14	11	12	11	7	13	15	13	11	3	0	9	6	3	11	10
232	5	6	4	3	7	8	4	12	11	10	9	1	6	13	10	10	4	1	6	4	3	9	8
233	5	8	13	7	4	8	5	0	10	14	13	9	9	4	13	4	2	8	7	11	9	6	9
235	9	8	8	0	7	11	7	9	8	7	14	6	5	10	10	6	12	13	6	5	4	9	8
236	8	12	19	12	10	11	11	11	15	13	15	10	17	11	14	13	3	0	8	8		14	13
243	12	0	17	11	4	6	10	11	7	3	5	7	5	8	3	6	8	6	14	8	9	14	10
250	4	3	6	2	3	6	6	3	4	8	10	14	4	3	6	0	1	3	1	3	4		8
254	7	4	7	5	13	11	3	7	12	5	2	3	12	10	11	8	7	6	1	9	9	10	10
255	9	8	10	12	10	16	11	7	10	1	1	11	11	11	3	10	11	5	1	6	8		12
256	4	4	2	0	11	9	7	11	4	7	7	10	10	8	4	6	9	12	9	15	8		9
258	10	3	8	9	7	12	0	1	4	2	0	10	8	7	2	5	7	2		4	6	9	7
259	4	3	1	0	6	5	5	8	8	9	5	8	4	5	5	3	7	10	8	9	5	8	8
262	2	2	0	9	4	3	5	3	3	5	9	3	8	6	5	2	6	11	9	3	3	2	8
263	3	9	4	4	3	8	8	11	2	7	9	5	7	10	3	5	11	12	10	6	15		11
269	9	9	2	2		5	9	9	5	7	7	5	5	2	1	3	0	3	11	8	6	6	12
276	3	6	6	8	2	4	2	4	6	9	7	4	7	8	4	0	10	9	8	5	9	5	15
279	2	3	6	0	0	8	8	5	9	12	5	9	4	5	3	4	12	3	13	7	6	2	9
284	6	5	3	2	4	9	12	9	9	11	6	1	2	5	3	9	11	10	6	13	6	8	10
285	8	8	11	7	8	8	13	11	8	9	5	0	2	4	12	5	8	13	7	15	9	7	13
286	7	10	5	7	11	3	9	5	14	13	1	9	14	7	12	3	6	7	8	9	3	9	9
287	5	11	4	5	9	2	10	4	16	15	4	10	14	5	10	5	5	6	6	9	3	12	9
288	11	9	8	8	14	3	13	7	14	15	0	14	16	7	13	3	9	9	6	13	2	8	10
289	10	8	8	6	13	3	7	9	16	16	0	16	16	4	14	6	11	8	4	10	3	10	10
290	7	3	8	5	11	4	4	7	12	10	0	15	13	3	8	5	5	6	6	7	2	6	8
293	9	5	7	5	11	3	6	10	14	15	1	15	13	3	10	6	9	8	7	8	4	9	9
294	7	4	8	6	13	5	2	7	14	6	2	16	14	3	7	5	6	6	5	7	2	7	8
295	9	5	10	6	12	7	3	7	13	8	5	14	12	4	8	7	4	7	5	5	0	6	9
300	12	13	6	2	8	3	8	9	11	14	9	13	4	1	11	0	3	5	3	12	15		7
303	9	11	0	4	6	7	3	6	7	5	11	13	5	9	10	7	6	9	5	4	3	7	8
304	8	10	2	3	8	9	5	7	6	5	9	9	6	10	11	9	9	11	6	7	4	5	10
305	8	9	0	3	5	6	7	3	3	1	10	11	4	9	9	6	5	9	7	1	7		7
311	7	10	10	0	2	4	4	9	7	8	6	2	1	4	14	0	9	4	4	10	7	7	7
312	12	10	9	0	7	8	7	9	5	5	4	3	6	6	10	7	7	5	[illegible]	9	7	1	8
313		12	7	5	3	4	9	7	4	4	0	3	3	2	8	5	3	7	4	8	8	7	8
315	5	7	6	9	10	8	13	0	7	4	10	11	9	8	8	9	5	10	10	10	2	13	8
316	10	7	6	7	11	1	10	6	12	10	1	11	14	5	7	3	4	6	6	10	4	11	11
317	6	13	14	8	3	9	5	6	6	6	4	0	11	3	17		6	7	4	4	10	10	9
318	0	10	7	7	12	6	13	6	13	11	10	10	14	8	14	10	6	10	5	11	5		10

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APPENDIX 3

The subarray having the highest amplitude is listed together with those subarrays that should be excluded in order to ensure maximum SNR for the particular beam location. The right column gives the expected gain by excluding these subarrays. For some of the beams there is a negative gain, which means that a loss in SNR would be encountered even by excluding only the subarray with the very lowest amplitude.

BEAM NO.	BEST SUB.	POOREST SUBARRAYS	GAIN BY EXCLUDING
8	13	5 19	0.2[illegible]
9	13	19 14 5	0.05
11	22	14	0.02
12	13	4 14 18	0.05
13	22	4	0.01
15	1	5	0.01
16	7	6	-0.01
17	1	4 19	0.11
20	7	6	0.01
21	11	6 2 1	0.14
23	13	6 1 2 4 5	0.20
24	11	1 2 6 4 5	0.19
25	11	2 8 6 4 7 17	0.22
26	13	2 8 19 4 7 6 18 1 14 17	0.31
27	13	18 8 7 19 16 2 15 17	0.10
29	3	8 19 15 18	0.18
31	13	8 2 7 6 18 19 1	0.20
32	13	8 2 18 7	0.10
33	13	22 8 7 18 19	0.26
34	3	8 19 15 18 7 2	0.35
35	13	8 19 18 2 15 7	0.28
36	3	19 8 15 16 20 14 6 5	0.20
37	3	8 19 15 14 20 16	0.31
42	3	19	0.01
43	17	6	0.01
48	18	12	-0.02
50	3	22	0.0
52	13	22 21 20 6 19	0.14
53	3	22 15 21 16 19 6	0.14
55	4	6 22 12	0.06
56	14	12 19 7	0.04
58	3	22 21 15 16 8 19 20 6 17 14	0.23
60	4	5 19 7 22	0.14
62	4	12 22 6 21 20 13	0.24
63	3	15 21 6 22 16 17 19 14 8 20	0.35
64	3	15 21 6 16 14 19 5 17 22	0.38
65	9	16 6 14 15 4	0.26
70	9	21 6 15 22 14	0.07
71	9	6 21 14 15 16	0.04
73	4	12	0.01
74	4	5	0.0
75	9	21 6 14	0.06
76	9	21 14 6 22	0.09
77	13	1 7 16 19 22 18 6 14	0.27
78	9	14	0.0
79	9	22 14 16 5 1 6 4 21 15 18 11 17 2 19 7	0.46

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BEAM NO.	BEST SUB.	POOREST SUBARRAYS	GAIN BY EXCLUD.
80	9	14 22 6	0.02
81	13	6 15 17 5 16 21 7 1 14 20 2 19 18	0.40
83	4	12	0.05
84	9	22	-0.01
86	9	22	0.06
87	13	16 18 22 14 17 6 1	0.21
89	8	22	-0.02
90	9	6 4 20 22	0.05
91	13	22 16 21 4 14 6	0.15
92	12	22 17	0.04
93	12	6 18 22 14 16 15 1 5 7	0.32
95	4	9 6	0.01
97	9	18 6 7 14 4	0.05
98	9	22	0.01
101	19	10 14 9	0.13
102	18	12	0.03
103	13	2	-0.01
104	1	15 9	0.07
105	20	10 8	0.06
106	12	20	0.03
107	13	18 6 2	0.08
110	20	9	0.0
112	12	2	0.0
113	14	21 19 15 18 10	0.19
115	19	17	0.0
116	12	6 14 4	0.03
119	14	11	0.01
120	21	17 2 6	0.02
121	21	17	0.0
122	9	2	0.02
123	9	20 6 2 7	0.10
124	3	20 6	0.02
125	14	7	0.07
126	14	19 20	0.03
127	1	9	0.03
129	3	6 2	0.03
131	13	22	-0.04
132	2	15	0.04
134	21	3 4	0.09
135	15	18	0.06
136	10	20	0.0
137	13	2	-0.01
138	18	7 6	0.13
139	13	7 17	0.06
140	1	19	0.03
141	13	21	0.0
142	13	15	-0.04
143	15	20	0.05

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BEAM NO.	BEST SUB.	POOREST SUBARRAYS	GAIN BY EXCLUD.
144	15	20 6 4 2 8	0.21
145	13	7	0.01
148	9	20 2 3 19	0.16
149	13	6	0.01
150	13	4 7 19	0.18
151	20	11	0.01
152	16	22 19	0.03
155	7	2	0.03
157	13	6	0.01
159	13	22	0.02
161	20	11	0.0
162	20	11	-0.02
164	7	15 21	0.06
165	20	19	-0.04
166	20	2	0.01
167	20	17	0.02
168	13	1	-0.01
169	13	18 19	0.07
170	13	18 19	0.06
171	10	2	0.01
172	4	17 7	0.09
175	1	17	-0.03
177	13	22 7	0.02
178	13	17 7 22	0.05
179	11	17 7 22 5 16 14	0.14
181	3	6	0.01
182	7	4	-0.02
183	11	17 1 22 7 14 16 18 6	0.27
184	11	7 19 1 22 18 14 17 5	0.36
186	2	17	0.03
187	13	22 17 16	0.13
188	11	17 7 14 18 5 16 1 6 22	0.26
189	11	17	0.09
190	12	6	0.01
191	8	19	0.01
192	11	7 18	0.04
195	11	18 1 22 7 17	0.26
197	11	1	-0.01
198	18	11 12 3 15 13 2 14	0.56
202	19	1 8	0.14
210	18	12	0.02
213	5	22 9	0.03
215	18	13	0.0
220	4	9	0.02
221	12	8	0.04
223	13	8 10	0.10
224	4	8	0.01
226	12	9	0.05

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BEAM NO.	BEST SUB.	POOREST SUBARRAYS	GAIN BY EXCLUD.
227	15	8 6 9	0.14
229	16	11 3 10 9	0.18
230	17	10 3 20 9 11 6	0.39
231	18	14 8	0.03
232	18	14 8	0.04
233	8	10 15 3 11	0.10
235	4	11	0.03
236	18	3 13 11 9	0.33
243	2	3 22 19 1	0.16
250	16	12 11	0.09
254	19	5 9	0.02
255	10	6	0.07
256	4	20	0.05
258	7	6 12	0.03
259	4	18	-0.03
262	3	18	0.03
263	9	21	0.06
269	17	19	0.04
279	5	19 17 10	0.14
284	12	20 7	0.04
285	12	20 18 7 15	0.09
286	11	13 9	0.05
287	6	9 10 13 22	0.18
288	11	13 10 12 5 9 7 15 20	0.21
289	11	10 12 13 9 15 5	0.30
290	11	12 13 9	0.13
293	11	10 12 9 13	0.14
294	7	12 9 13 5	0.24
295	21	12 9 13 5	0.08
300	16	21 10 12 2 1 20 9 15	0.25
303	3	12	0.01
304	3	15	-0.03
305	3	12	-0.02
311	16	15	0.07
312	4	1	0.0
313	11	2	0.03
315	8	7	-0.01
316	11	13 9	0.06
317	12	15 3 2	0.15
318	1	15	0.01

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